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ENVIRONMENTAL ASSESSMENT**

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**OF THE EFFECTS OF CONTROLLED EXPOSURE OF SOUND ON THE BEHAVIOR  
OF VARIOUS SPECIES OF MARINE MAMMALS**

**APRIL 2003**

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NOAA Fisheries, Office of Protected Resources

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**Abstract:** NOAA Fisheries, Office of Protected Resources, proposes to issue a scientific research permit for takes of various species of cetaceans in the wild, pursuant to the Marine Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1361 et seq.), and the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.). The primary objective of the proposed action is to collect information on the biology, foraging ecology, behavior, and communication of a variety of cetacean species with a focus on examining the effects of underwater noise on these aspects. A secondary objective is to test the efficacy of a new mid- high (1kHz-12kHz) frequency whale-finding sonar designed to be used in marine mammal conservation. Scientific research permits are generally categorically excluded from the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 et seq.) requirements to prepare an environmental assessment (EA) or environmental impact statement (EIS) (NAO 216-6). However, because of the nature of the proposed research, NOAA Fisheries concluded that further environmental review was warranted to determine whether significant environmental impacts could result from issuance of the proposed scientific research permit. Therefore, this document evaluates the relevant effects of a variety of scientific research activities on cetacean species under alternative permitting options.

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**ON THE EFFECTS OF CONTROLLED EXPOSURE OF SOUND ON THE BEHAVIOR  
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**CHAPTER 1 PURPOSE OF AND NEED FOR ACTION**

**1.1 Description of Action**

The NOAA Fisheries proposes to issue a scientific research permit for takes<sup>1</sup> of marine mammals, including endangered species, in the wild, pursuant to the Marine Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1361 et seq.), and the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.). An application for a scientific research and enhancement permit was received from Dr. Peter L. Tyack, Biology Department, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 02543 (File No. 981-1707).

Issuance of scientific research permits is among a category of actions that are exempted (categorically excluded) from further environmental review, except under extraordinary circumstances. The regulations governing issuance of special exception permits for scientific research (50 C.F.R. §216.33) require an initial determination as to whether the activities proposed in the permit applications meet the criteria for a categorical exclusion. When a proposed action that would otherwise be categorically excluded meets any of the following conditions: 1) is the subject of public controversy based on potential environmental consequences; 2) has uncertain environmental impacts or unknown risks; 3) establishes a precedent or decision in principle about future proposals; 4) may result in cumulatively

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<sup>1</sup> Under the MMPA, "take" is defined as to "harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect." "Harass" is further defined as "Any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild (Level A harassment); or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but does not have the potential to injure a marine mammal or marine mammal stock in the wild (Level B harassment)." [16 U.S.C. 1362(18)(A)] The ESA defines "take" as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

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significant impacts; or 5) may have an adverse effect upon endangered or threatened species or their habitats, an EA is prepared in order to determine if an EIS is required.

Dr. Tyack requests authorization for a five year permit to take various cetacean species, including endangered whales, for scientific purposes related to the biology, foraging ecology, communication, and behavior of these animals, with a focus on their responses to anthropogenic sounds in the marine environment. Takes would include harassment during close approach for behavioral observations, attachment of scientific instruments, controlled exposure to playbacks of a whale-finding sonar, airgun sounds, and sperm whale (*Physeter macrocephalus*) social vocalizations (codas).

The permit application covers three research projects on a variety of marine mammals including endangered species in the North Atlantic (including the Gulf of Mexico) and Mediterranean Sea. The principle research technique for all three projects involves short-term tagging (via suction cup mounted instruments) of marine mammals with an advanced digital sound recording tag (DTAG) that can record the acoustic stimuli an animal hears, while also measuring the whale's vocal, behavioral, and physiological responses to sound.

Project 1 involves studying the baseline behavior of animals tagged throughout the North Atlantic. There are three main goals of the Project 1 tagging. The first goal is to obtain continuous sampling of marine mammal vocal and motor behavior. DTAGs collect information on feeding ecology, diving, vocalizations and social behavior that is impossible to obtain solely via surface observations. The researcher hopes to tag some species, such as Cuvier's beaked whale (*Ziphius cavirostris*), whose vocalizations are poorly described in the literature with the hopes of understanding their foraging and social behavior and possibly using acoustics to detect their presence in the future. Tagging of other species, such as pilot whales (*Globicephala* sp.), may yield new information about their social behavior and communication. The second goal of the Project 1 tagging is to provide a basis for determining correction factors to visual sighting data. Information such as dive, surfacing, and blow patterns can help determine the availability of a species to be seen by a visual observer and thus provide a better estimate of population

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and/or stock abundance. The third goal of Project 1 is to serve as an additional control group for the playbacks of Projects 2 and 3. Although the playbacks are designed with a pre-exposure period to observe behaviors prior to playback, the data collected in Project 1 will also serve as a comparison for behaviors seen during and after controlled playbacks.

For the second project (Project 2), tagged animals will be used as test subjects in controlled field verification tests of a whale-finding sonar in the Mediterranean Sea. No animal will experience received levels exceeding 160 dB re 1  $\mu$ Pa rms. Playbacks of sperm whale codas will be used as a control stimulus. Some anthropogenic sound sources (*e.g.*, those used for oil and gas exploration) are so loud that they pose a risk of injuring animals that are too close. The zone of injury for such sources may extend hundreds of meters away from some sources (Richardson *et al.* 1995). The possibility of injury creates a need to monitor the surrounding area to ensure that no marine mammals or endangered animals such as sea turtles are in this zone of potential injury. Monitoring techniques have typically been visual observations and passive acoustic listening; however, it has been increasingly recognized that these methods are not 100% effective (*e.g.*, at night, during poor weather, when animals are silent). The need for a more effective detection tool has led to development of very low power, mid-high frequency<sup>2</sup> (1kHz-12kHz) active sonars that can detect marine mammals or sea turtles within a range of 1-2 km. The goal of the Project 2 playback experiment is to validate the effectiveness of a whale-finding sonar, to calibrate measurements of the target strength<sup>3</sup> of marine mammals as a function of aspect, and to assess the received levels at which animals that can hear the sonar may start to show changes in behavior.

For the third project (Project 3) the responses of tagged sperm whales to short impulses from airgun arrays at received levels no higher than 180 dB re 1  $\mu$ Pa rms will be studied in the Gulf of Mexico. Playbacks of sperm whale codas will be used as a control stimulus. Most data on

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2 Conventional science defines frequency ranges of sound as: low < 1kHz, mid = 1-12kHz, and high > 10kHz.

3 Target strength is a measure of how well an object reflects sound. It is defined as the ratio of sound energy reflected from an object divided by the sound energy hitting the target, expressed in dB (Urick 1983). Objects with higher target strength will return stronger signals to the sonar receiver.

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responses of sperm whales to manmade sounds concern sounds from airguns used for seismic exploration, and this is the sound source of most concern for sperm whales in the Gulf of Mexico. The seismic industry is primarily interested in directing sound energy into geological strata below the seafloor; therefore it uses arrays of airguns to direct low frequency sound downwards. Airguns generate sound by releasing compressed air into the seawater from a chamber. As the bubble expands and collapses, it generates an impulse sound. Technical advances in the oil industry are allowing exploration and drilling for petroleum in much deeper water than in the past. As oil industry activities move into the deep water habitat of sperm whales, airgun use may have an increasing impact on deep divers such as sperm whales. According to Cranswick and Regg (1997), 83% of the crude oil production and 99% of the gas production in U.S. Federal waters occurs in the Gulf of Mexico. Most projections predict strong expansion of oil industry activities into the deep water habitat of sperm whales in the Gulf of Mexico.

There are conflicting accounts on the effects of sounds on large deep-diving toothed whales and it is currently unknown what maximum levels of exposure are safe, and what levels may lead to significant disruption of critical behaviors. A major obstacle to these studies has been the inability to monitor responses when whales are at depth. Dr. Tyack proposes to use the DTAG to resolve differences in results from earlier studies of how likely sperm whales are to silence, move away, or show other disruption of behavior when they are exposed to impulse sounds from an airgun array versus natural control sounds. These studies will involve visual observations of surfacing sperm whales, passive acoustic tracking of diving sperm whales, and tagging sperm whales with DTAGs. The primary research objective of the Project 3 airgun playbacks is to determine what characteristics of exposure to specific sounds evoke behavioral responses in marine mammals, which is an important issue for marine mammal conservation and for NOAA Fisheries regulators.

All three proposed projects involve potential takes by harassment during close approaches for tagging, attachment of tags, “focal follows” (*i.e.*, following a tagged whale to observe its

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behavior), and for Projects 2 and 3, playbacks of sound. When the DTAGs are retrieved after release, small fragments of sloughed skin are often found in the suction cup. These tissue samples will be exported from field sites and imported for genetic analyses.

### **1.1.1 Background**

Over the past 50 years, economic and technological developments have increased the human contribution to ambient noise in the ocean. Shipping is the overwhelmingly dominant source of manmade noise in the ocean (Green *et al.* 1994). Ambient noise levels in the oceans are reported to have increased 10 dB from the 1960's to the 1990's due to shipping (Andrew *et al.*, 2002). A wide variety of artificial sound sources could affect marine mammals, including explosive sources as used during oil and gas exploration, general ship noise, active sonar, and seismic exploration. Loud low frequency sound sources are increasingly being employed for long range sonar, oceanographic and geophysical research, and communication in the sea. The oil industry studies geological formations deep below the sea surface by using arrays of airguns to make sounds intense enough for echoes of geological strata to be detected kilometers away. In the Gulf of Mexico, over 200,000 miles are surveyed each year in this manner (MMS data). As technology advances, the oil and gas industry is able to explore and drill in much deeper water, possibly increasing the impact on deep divers like sperm whales. Typical peak-to-peak energy source levels for the pulses produced by airgun arrays used for seismic exploration range from 235- 269 dB re 1  $\mu$ Pa peak at 1 m with pulse durations of several tens of milliseconds repeated every 10 sec or so (Richardson *et al.* 1995). Military sonars have had high energy source levels since World War II.

There is growing evidence that some man-made sounds can disturb marine mammals, and the issues concerning the effects on marine mammals of man-made sound have received increasing attention (Green *et al.* 1994; Richardson *et al.* 1995) within the scientific community and from the public. Observed responses of marine mammals to man-made sounds include silencing, disruption of activity, and movement away from the source (Chapter 9, Richardson *et al.* 1995).

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The zone of influence of a sound source depends upon its energy level (usually measured in dB), its frequency spectrum, its duration, and the conditions for sound propagation near the source (Chapter 10, Richardson *et al.* 1995). Low frequency sound carries well under some circumstances, and animals several tens of kilometers away from intense acoustic sources may show behavioral responses (Finley *et al.* 1990, Cosens and Dueck 1986). Marine mammals rely on sound for communication, orientation, and detection of predators and prey. Prolonged disruption of any of these functions would be of concern.

Public concern for the protection of marine mammals from underwater human noise has increased in recent years. Projects such as the Heard Island Feasibility Test, Acoustic Thermometry of Ocean Climate, and ship shock trials<sup>4</sup>, as well as the beaked whale strandings observed near military mid frequency sonar exercises have triggered speculation about the effects of human noise on marine species. Some underwater explosions and other man-made sounds may harm or harass marine mammals.

In order to understand the biological impact of any behavioral disruption caused by exposure to noise, the function of the behavioral activities in which the animal is engaged prior to the disturbance must be known. Sound can play a major role in the lives of marine mammals; for example, it is used for navigation, detection and localization of prey, and for mediating social interactions. Prolonged disruptions of any of these functions could alter reproduction or survival. There is a need for systematic research on how marine mammals respond to such acoustic events as a function of energy level, sound pressure level, rise time, frequency, and other features. One critical need is for research on the behavioral reactions of animals to sound. Behavioral reactions to a given signal may differ according to age, sex, time of season, context, and many other variables, and cannot be predicted at present.

### **1.1.2 Purpose and Need**

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<sup>4</sup> In shock trials, a submarine or surface ship is subjected to a series of underwater explosions to test how the ship will react to the effects of conventional and nuclear weapons.

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The primary purpose of the proposed permit is to authorize takes of marine mammals, including endangered species, for scientific research on the biology, foraging ecology, communication and behavior of marine mammals, with a focus on their responses to anthropogenic sounds in the marine environment.

The need for the proposed action arises from several sources. First, NOAA Fisheries has a responsibility to implement both the MMPA and the ESA to protect, conserve, and recover threatened and endangered marine mammals under its jurisdiction. The MMPA and ESA prohibit takes of threatened and endangered marine mammals with only a few very specific exceptions, including for scientific research and enhancement purposes. Permit issuance criteria require that research activities are consistent with the purposes and policies of these Acts and will not have a significant adverse impact on the species or stock.

A second reason for the proposed action is the need for collecting and analyzing additional information on the biology and ecology of these species, especially on the effects of anthropogenic sounds on marine mammals. This information is needed by NOAA Fisheries to make conservation and management decisions that work to protect marine mammals and that facilitate the recovery of those endangered marine mammals. Data are needed on the effects of sound on the behavior, communication and feeding ecology of marine mammals.

### **1.1.3 Objectives**

The objective of the proposed action is to authorize takes of marine mammals, including endangered whale species, for scientific research that will contribute significantly to identifying, evaluating, or resolving conservation problems for these species.

## **1.2 Other EA/EIS that influence the scope of this EA**

A number of Environmental Assessments (EA) have been prepared on the effects of some of the

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proposed research techniques being considered in the proposed action (*i.e.*, close approach, suction cup tagging, and controlled exposure to sound).

In 1992, NOAA Fisheries prepared an EA on the Effects of Biopsy Darting and Associated Approaches on Humpback Whales and Right Whales in the North Atlantic (NMFS 1992a). The EA was prepared in response to continued public concern surrounding the biopsy darting of endangered cetaceans, apparent uncertainty about the effects on individual animals/populations of repeated approaches associated with the biopsy darting procedure, and the fact that several permits had previously been issued for the same procedure. Eliminating projectile biopsies from the proposed activities was designated as the No Action alternative. In addition to the Proposed Action and No Action alternatives, an “Alternative test methods” alternative was evaluated in which skin samples would only be collected non-intrusively via sloughed skin samples from free-ranging animals and biopsy samples from dead-at-sea and live/dead stranded whales. The preferred alternative was the proposed action of issuing permits to authorize projectile biopsy darting with mitigation measures intended to minimize the potential for adverse effects of the research on the whales. A Finding of No Significant Impact (FONSI) was signed by the Acting Assistant Administrator for Fisheries on June 16, 1992, based on the best available information suggesting that careful approaches to whales, even repeated approaches, elicited only moderate or minimal reactions, and that most whales showed no observed change in behavior in response to biopsy darting.

NOAA Fisheries prepared an EA on the Effects of Biopsy Darting, Suction Cup Tagging and Associated Approaches on Humpback and Killer Whales in the Eastern North Pacific in 1994 (NMFS 1994). The issues prompting preparation of the 1994 EA were the same as those stated for the 1992 EA on the effects of these activities. However, new applications for permits were received for research on species/stocks of whales that were not considered in the previous EAs. There were four alternatives considered in the EA. Based on the best available information suggesting that the proposed action would have little if any short- or long-term effects on the subject whales and their populations a FONSI was signed by the Acting Assistant Administrator

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for Fisheries. Since this EA was prepared, there have been no negative or unexpected effects observed associated with suction cup tagging.

In response to a previous scientific research application (Permit No. 981-1578) from the current applicant, Dr. Tyack, for research involving exposure of marine mammals to mid and high frequency sound, and in light of the high degree of public interest in acoustic experiments involving free-ranging whales at the time, NOAA Fisheries prepared an EA on the effects of controlled exposure of sound on the behavior of various species of marine mammals (NMFS 2000). The primary research objective was to determine what characteristics of exposure to specific sounds evoke minor behavioral responses in marine mammals. The EA examined the environmental consequences of two alternatives: No Action (denial of the permit) and the Proposed Action (permit issuance), which included mitigation measures that would be instituted as part of the permit. The specific playback protocols examined involved exposure of animals to playbacks of low-power mid- high-frequency active sonar designed to detect marine mammals. The proposed received levels for the playbacks were not to exceed 160 dB. Other characteristics of the signals included bandwidths of 100, 200, and 400Hz; pulse durations of 50, 100, 200, and 400 milliseconds; chirp upsweeps centered at 1, 2.5, 4, 8, and 12kHz; and a pulse repetition rate of not more than one ping per minute. A FONSI was signed on August 31, 2000, based on information indicating that the short-term impacts of conducting acoustic playback experiments on cetaceans would not result in more than a temporary shift in the hearing thresholds of some individual cetaceans, and that changes in the behavior (to avoid the sounds) of individual animals were expected to have negligible impacts on the animals.

The effects of close approach, suction cup tagging, and acoustic playback experiments on marine mammals authorized under scientific research permits have been addressed in previous EAs and associated Biological Opinions and found to pose no significant potential for adverse impacts. Nevertheless, the protocols currently being requested by Dr. Tyack differ from those discussed in the 2000 EA and thus NOAA Fisheries is reexamining the potential effects of the proposed scientific research.

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### **1.3 Decision and other agencies involved in this analysis**

The Director, Office of Protected Resources (OPR), NOAA Fisheries (Office Director) must decide whether authorizing the new permit would be consistent with the purposes and policies of the MMPA, ESA and their implementing regulations, including making certain the permitted activities will not operate to the disadvantage of any marine mammal species.

During preparation of this draft EA, Notice of Receipt of the application File No. 981-1707 had not yet been published in the *Federal Register* for public comment, nor had the application been sent to the Marine Mammal Commission (MMC) for review because the Office Director determined the need for an EA upon receipt of the application. Therefore, with the publication of this EA as a draft document and the concurrent Notice of Receipt of the permit application, the Office Director is requesting the comments from the public and the MMC on both the EA and the application File No. 981-1707, pursuant to 50 CFR § 216.33 (d)(2). No other Federal, state, or local agencies are involved in the proposed action.

### **1.4 Scoping Summary**

Upon receipt of a valid and complete application for a scientific research permit, the Office Director publishes a Notice of Receipt in the *Federal Register* that summarizes the application including: the type and manner of special exception activity proposed, the location in which the marine mammals will be taken, and the requested period of the permit 50 CFR §216.33 (d)(1)). This notice also lists where the application will be available for review and invites all interested parties to submit written comments concerning the application within 30 days of the date of the notice. Concurrent with publication of this notice, the Office Director forwards a copy of the complete application to the MMC for comment (50 CFR §216.33 (d)(2)). The application is also forwarded to NOAA Fisheries Regional Offices and Science Centers in the area where the proposed research would occur, and independent scientific experts, as appropriate (50 CFR §216.33 (d)(3)).

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#### **1.4.1 Scoping for File No. 981-1707 (Dr. Peter Tyack)**

Concurrent with the publication in the Federal Register of the availability of this EA as a draft will be a notice of receipt of application File No. 981-1707. Both documents will be available to all interested parties for comment for a period of 30 days. Copies of the draft EA and the permit application will be submitted to the Marine Mammal Commission as well as to NOAA Fisheries Regional Offices and Science Centers.

Since takes of endangered species are included in the proposed research, the NOAA Fisheries OPR, Permits, Education and Conservation Division (Permits Division) will initiate consultation with the Endangered Species Division under Section 7 of the ESA. A Biological Opinion will be prepared that examines the potential of the proposed action to adversely affect listed species or adversely modify critical habitat. When finalizing the EA and making a final determination on the issuance of the permit, NOAA Fisheries will take into account comments received on the application and the draft EA, as well as the recommendations of the Biological Opinion.

#### **1.4.2 Issues within the scope of this analysis**

In accordance with NOAA Fisheries' implementing regulations under the ESA and MMPA, and its NEPA administrative order, this document examines the need for the proposed research and whether the proposed research will have short or long-term direct or indirect effects on the requested species and the human environment.

This document is being prepared following litigation involving Dr. Tyack's original permit (No. 981-1578), in which the court issued a decision overturning particular aspects of that permit (Hawaii County Green Party vs. Evans, C-03-0078-SC, U.S. District Court, Northern District of California). This current permit authorized a suite of research activities, most very similar to the research proposed in the new application (No. 981-1707). Research included attachment of

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DTAGs, whale-finder sonar testing, playbacks of sperm whale vocalizations, and seismic airgun playbacks.

With only the current Permit No. 981-1578 and one amendment still valid, the researcher is limited in the research that he can conduct. Dr. Tyack has decided to apply for a new research permit that incorporates his current research plans. Two projects that were part of the current permit have not been requested by Dr. Tyack in this current application: 1) testing of the whale-finder sonar developed by Scientific Solutions, Inc. on gray whales in the Pacific and 2) tagging of animals including humpback whales in Pacific waters. Though many of the research techniques that Dr. Tyack is planning to employ were already examined in the EA written for his current permit, NOAA Fisheries has elected to prepare another EA to comprehensively reexamine the issues.

NOAA Fisheries has determined that the best course of action is to issue a new permit to Dr. Tyack for all his research activities in the Atlantic and Mediterranean Sea, and to analyze all those activities in a new EA. Should Permit No. 981-1707 be issued to Dr. Tyack, he plans to withdraw his current permit, so there will be no duplicative takes occurring.

Close approach for behavioral observation and attachment of scientific instruments are widely used techniques whose effects on whales have been well documented and reviewed. Thus, the primary purpose of this environmental assessment is to review the available scientific information on the potential impacts of sound on marine animals and the human environment, particularly the potential impacts of exposure to the sounds as proposed in the application for a permit.

### **1.5 Federal permits, licenses, and entitlements necessary to implementation of the action**

*Marine Mammal Protection Act permits.* A moratorium on the taking of marine mammals in U.S. waters and by U.S. citizens on the high seas was established with passage of the Marine

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Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1361 et seq.). The MMPA provides that this moratorium on taking of marine mammals can be waived for specific purposes, if the taking will not disadvantage the affected species or stock. Section 104 of the MMPA allows for issuance of permits to take marine mammals for the purposes of scientific research or to enhance the survival or recovery of a species or stock. These permits must specify the number and species of animals that can be taken, and designate the manner (method, dates, locations, etc.) in which the takes may occur.

*Endangered Species Act permits.* Section 9 of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et seq.*) and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Permits to take ESA-listed species for scientific purposes (or for the purpose of enhancing the propagation or survival of the species) may be granted pursuant to Section 10 of the ESA and in accordance with NOAA Fisheries' implementing regulations.

*Convention on International Trade in Endangered Species of Flora and Fauna (CITES).* Signed in 1973, in response to an urgent need to control commercial trade in rare wildlife worldwide, the CITES restricts or prohibits trade in live or dead wildlife and their parts for those species listed on three appendices, which are based on the level of endangerment of the species. The ESA implements the CITES treaty for the United States. Thus, it is unlawful to trade or possess any specimens traded in violation of CITES. However, species and parts listed in the appendices may be imported and exported with a valid CITES permit obtained from the U.S. Fish and Wildlife Service, Office of Management Authority. For endangered species, a permit issued under Section 10 of the ESA is also required for import and export. Holders of MMPA/ESA permits for scientific research issued by NMFS are responsible for obtaining the appropriate CITES permits following receipt of their NOAA Fisheries permit and prior to any import or export of species listed on the CITES appendices.

### **1.5.1 Brief overview of process for obtaining a NOAA Fisheries Scientific Research Permit (SRP) under MMPA and ESA**

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Persons seeking a special exception permit for scientific research must submit a properly formatted and signed application to the Office Director. The applicant must describe the species to be taken, the manner and duration of the takes, the qualifications of the researchers to conduct the proposed activities, as well as provide justification for such taking. Upon receipt, applications are reviewed for completeness according to the specified format and for compliance with regulations specified at 50 CFR §216.33. At this time, an initial determination is made as to whether the proposed activity is categorically excluded from the need to prepare an EA or EIS. A Notice of Receipt of complete applications must be published in the *Federal Register*. This Notice invites interested parties to submit written comments concerning the application within 30 days of the date of the Notice. At the same time, the application is forwarded to the MMC and other reviewers for comment. In addition, if endangered species are likely to be affected by the proposed activities, the Permits Division must consult with NOAA Fisheries Endangered Species Division (or the U.S. Fish and Wildlife Service if species under their jurisdiction are involved). At the close of the comment period, the applicant may need to respond to requests for additional information or clarification from reviewers. If the proposed activities do not meet the criteria for a categorical exclusion, the appropriate environmental documentation (EA or EIS) must be prepared and is subject to public comment. If all concerns can be satisfactorily addressed and the proposed activity is determined to be in compliance with all relevant issuance criteria (see sections 1.5.2 and 1.5.3), the Office Director will issue a permit.

### **1.5.2 MMPA regulations regarding issuance of SRPs**

The regulations promulgated at 50 CFR §216.33, §216.34, and §216.41 specify criteria to be considered by the Office Director in making a decision regarding issuance of a permit or an amendment to a permit. Specifically, §216.33(c) requires that the Office Director: (a) make an initial determination under NEPA as to whether the proposed activity is categorically excluded from preparation of further environmental documentation, or whether the preparation of an environmental assessment (EA) or environmental impact statement (EIS) is appropriate or necessary; and (b) prepare an EA or EIS if an initial determination is made that the activity proposed is not categorically excluded from such requirements. The permit issuance criteria

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listed at §216.34 require that the applicant demonstrate that:

- (1) The proposed activity is humane and does not present any unnecessary risks to the health and welfare of marine mammals.
- (2) The proposed activity is consistent with all restrictions set forth at §216.35 and any purpose-specific restrictions as appropriate set forth at §216.41, §216.42, and §216.43.
- (3) The proposed activity, if it involves endangered or threatened marine mammals, will be conducted consistent with the purposes and policies set forth in section 2 of the ESA.
- (4) The proposed activity by itself or in combination with other activities, will not likely have a significant adverse impact on the species or stock.
- (5) The applicant's expertise, facilities, and resources are adequate to accomplish successfully the objectives and activities stated in the application.
- (6) If a live animal will be held captive or transported, the applicant's qualifications, facilities, and resources are adequate for the proper care and maintenance of the marine mammal.
- (7) Any requested import or export will not likely result in the taking of marine mammals or marine mammal parts, beyond those authorized by the permit.

In addition to these requirements, the issuance criteria at §216.41(b) require that applicants for permits for scientific research and enhancement must demonstrate that:

- (1) The proposed activity furthers a *bona fide* scientific or enhancement purpose.
- (2) If the lethal taking of marine mammals is proposed:
  - (a) Non-lethal methods for conducting the research are not feasible; and
  - (b) For depleted, endangered, or threatened species, the results will directly benefit that species or stock, or will fulfill a critically important research need.
- (3) Any permanent removal of a marine mammal from the wild is consistent with any applicable quota established by the Office Director.
- (4) The proposed research will not likely have significant adverse effects on any other

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component of the marine ecosystem of which the affected species or stock is a part.

(5) For species or stocks designated or proposed to be designated as depleted, or listed or proposed to be listed as endangered or threatened:

(a) The proposed research cannot be accomplished using a species or stock that is not designated or proposed to be designated as depleted, or listed or proposed to be listed as threatened or endangered;

(b) The proposed research, by itself or in combination with other activities will not likely have a long-term direct or indirect adverse impact on the species or stock;

(c) The proposed research will either:

(i) Contribute to fulfilling a research need or objective identified in a species recovery or conservation plan, or if there is no conservation or recovery plan in place, a research need or objective identified by the Office Director in stock assessments established under Section 117 of the MMPA;

(ii) Contribute significantly to understanding the basic biology or ecology of the species or stock, or to identifying, evaluating, or resolving conservation problems for the species or stock; or

(iii) Contribute significantly to fulfilling a critically important research need.

### **1.5.3 ESA regulations regarding issuance of SRPs**

NOAA Fisheries' regulations implementing the ESA at 50 CFR §222.308(b) provide that "Permits for marine mammals shall be issued in accordance with the provisions of part 216, subpart D of this chapter" as outlined in the previous subsection of this EA. In addition to these issuance criteria under the MMPA, NOAA Fisheries' regulations implementing the ESA at 50 CFR §222.308(c) require that the following criteria be considered in determining whether to issue a permit for scientific purposes for takes of endangered species:

(1) Whether the permit, if granted and exercised, will not operate to the disadvantage of the endangered species;

(2) Whether the permit would be consistent with the purposes and policy set forth in

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section 2 of the ESA;

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(3) Whether the permit would further a *bona fide* and necessary or desirable scientific purpose or enhance the propagation or survival of the endangered species, taking into account the benefits anticipated to be derived on behalf of the endangered species;

(4) Whether alternative non-endangered species or population stocks can and should be used;

(5) Whether the expertise, facilities, or other resources available to the applicant appear adequate to successfully accomplish the objectives stated in the application; and

(6) Opinions or views of scientists or other persons or organizations knowledgeable about the species which is the subject of the application or of other matters germane to the application.

Under section 7 of the ESA, the Permits Division, as a Federal action agency, is required to determine whether issuance of a permit may affect listed species or critical habitat. If it is determined that issuance of a permit may adversely affect listed species or adversely modify critical habitat, the Permits Division must formally consult with the Endangered Species Division. In requesting this consultation, the Permits Division is required to provide the best scientific and commercial data available for an adequate review of the effects of the proposed permit on listed species and critical habitat (50 CFR §402.14). Although both the MMPA and ESA definition of a “take” include harassment, the ESA does not define harassment. However, harassment has been defined in Biological Opinions prepared during consultations on issuance or marine mammal research permits, as injury to an individual animal or population of animals resulting from a human action that disrupts one or more behavioral patterns that are essential to an individual animal’s life history or to the animal’s contribution to a population, or both. Particular attention is given to the potential for injuries that may manifest themselves as an animal that fails to feed successfully, breed successfully (which can result from feeding failure), or complete its life history because of changes in its behavioral patterns. In the latter two of these examples, the injury to an individual animal could be injurious to a population because the individual’s breeding success will have been reduced.

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## **CHAPTER 2 ALTERNATIVES INCLUDING THE PROPOSED ACTION**

This chapter describes the range of potential actions (alternatives) determined reasonable with respect to achieving the stated objective and also summarizes the related mitigation of each alternative. Although there are several possible combinations of the proposed research activities that could be considered as alternatives, there is a limited range of alternatives that could reasonably achieve the need that the proposed actions are intended to address without violating any environmental standards, including the MMPA and ESA. One alternative is the No Action alternative, or Status Quo alternative, where the proposed permit would not be issued. No Action does not mean that there will be no environmental consequences, because the existing environment is not static, and because under no further action, Dr. Tyack is authorized to conduct some research under his current permit (No. 981-1578) and because commercial and military use of sound in the marine environment will continue. The Status Quo is the baseline for rest of the analyses. The Proposed Action alternative represents all of the research proposed in the submitted application. Another alternative that authorized the proposed research, but required the applicant to use lower sound levels was eliminated because it did not facilitate the development of a whale-finding sonar that can be used to detect marine mammals underwater.

### **2.1 Alternative 1: No Action**

Under the No Action alternative, which describes the Status Quo conditions (baseline), a permit would not be issued and the scientific research proposed in File No. 987-1707 would not take place. Without the permit, there will still be sources of anthropogenic sound in the marine environment that may affect marine mammals. Without the proposed research occurring, new information and an increased understanding of the effects of sound in the marine environment would not be gained.

As mentioned in Section 1.4.2, Dr. Tyack was issued a scientific research permit (No. 981-1578) in 2000. The permit and subsequent amendments were the subject of recent litigation which resulted in two of the amendments being invalidated by the judge. As a result, Dr. Tyack can currently only conduct the research authorized by the original permit and one amendment. The

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permitted research is limited to the Mediterranean and Ligurian Seas and the waters off the coast of the Azores. Techniques involve attaching suction cup DTAGs to fin (*Balaenoptera physalus*), sperm, beaked, pygmy and dwarf sperm (Kogia sp.), and pilot (*Globicephala* sp.) whales, as well as bottlenose (*Tursiops truncatus*), common (*Delphinus delphis*), striped (*Stenella coeruleoalba*), rough-toothed (*Steno bredanensis*), and Risso's dolphins (*Grampus griseus*). Sperm whales could also be tagged with DTAG that is implanted in the blubber. The original permit also authorizes testing of a mid frequency, low power, whale-finder sonar with source levels of 160-180 dB re 1  $\mu$ Pa at 1 m, and received level at the animal of 160 dB. Other species such as humpback (*Megaptera novaeangliae*), minke (*B. acutorostrata*), sei (*B. borealis*), blue (*B. musculus*) killer (*Orcinus orca*), false killer (*Pseudorca crassidens*), and bottlenose (*Hyperoodon ampullatus*) whales, and Atlantic spotted dolphins (*Stenella frontalis*) may be unintentionally exposed to the whale-finder sonar, but would not be tagged.

Theoretically, Dr. Tyack could choose to conduct the research authorized by Permit No. 981-1578, if the proposed permit is not issued. However, the usefulness of that research is limited. Dr. Tyack has already conducted tests of the whale-finder sonar as described in Permit No. 981-1578 and it was unsuccessful at those source levels. Increased source levels are needed to continue testing the whale-finder sonar and those levels are not currently authorized under Permit No. 981-1578. The current permit has a very limited geographic range and does not include tests to observe the effects of seismic airgun arrays on marine mammal behavior. Should Permit No. 981-1707 be issued to Dr. Tyack, he plans to withdraw his current permit, so there will be no duplicative takes occurring

**2.2 Alternative 2 – Proposed Action: Issue Permit as requested by applicant**

Under this alternative, a permit would be issued and the proposed scientific research described below and in the permit application would take place. The proposed research is divided into three research projects; the objectives and goals of these distinct projects are outlined in Section 1.1.

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### **2.2.1 Project 1: Tagging animals in the North Atlantic (including Mediterranean Sea and Gulf of Mexico)**

Dr. Tyack proposes to tag various species of whales and dolphins in a variety of settings without conducting playback experiments. The species requested to be tagged are: humpback, minke, Bryde's (*Balaenoptera edeni*), sei, fin, blue, sperm, bottlenose, beaked, pilot, melon-headed (*Peponocephala electra*), killer, false killer, and pygmy killer whales (*Feresa attenuata*) and bottlenose, common, Atlantic spotted, pantropical spotted (*Stenella attenuata*), spinner (*S. longirostris*), striped, clymene (*S. clymene*), rough-toothed, Fraser's (*Lagenodelphis hosei*), and Risso's dolphins. See Section 3.4 for a description of each species' distribution and abundance.

The acoustic recording tag, or DTAG, offers a direct means to measure acoustic and motor behavior. By simultaneously recording the received level of sound at the animal together with physiological and behavioral signals, the connection between sound and behavioral or other response can be made directly. Other advantages of the DTAG include: 1) the sound level at the animal (*i.e.*, received level, RL) is measured directly, 2) there are no time alignment errors when correlating sound exposure and behavioral response, and 3) it is possible to measure subtle and short-duration responses, *e.g.* fluke stroke frequency and amplitude, allowing lower exposure levels to be used.

Two versions of the DTAG will be employed. The original DTAG has dimensions of approximately 4" x 3" x 1", dramatically smaller than many other existing tags. A more recent version of the DTAG has outside dimensions (including packaging) of 4.4" x 1.6" x 1", which is 40% less than the volume of the earlier DTAG design. Both DTAGs incorporate a digital signal processor capable of real-time detection and compression of audio signals, making efficient use of memory. The sampling rate and compression algorithm used by the tag are fully programmable. The tag also includes sensors for pressure, pitch, roll, heading, surfacing events, and temperature. All programming and data are downloaded through an infrared communications port enabling the entire system to be potted and eliminating the need for a pressure housing, thereby further increasing the efficiency and robustness of the instrument in

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the field. The DTAG itself has no inherent attachment mechanism, so that attachment can be customized for the species being studied. The new DTAG version has a modular audio acquisition section and can be assembled with a high performance stereo ADC (24 bits, 96kHz/channel) suitable for sperm whales and baleen whales, or with a high speed ADC (12 bits, 300-400kHz, single channel) for small odontocetes. The sensor suite on the newer tag is the same as the older version with the addition of an EKG sensor.

The DTAG was designed to acquire data at high rates so that fine details of an individual's behavior can be documented. Being a high data rate tag, the DTAG need only be attached to an animal for relatively short periods of time (*i.e.*, 5-48 hours). Dr. Tyack believes that non-invasive attachment mechanisms are the most appropriate to meet the target life of a few hours to a day or two. The most appropriate non-invasive method for the temporary, external attachment of the DTAGs on most cetacean species involves the use of suction cups.

The basic principle for tag delivery is to minimize the potential for disturbing the whale or dolphin. For large, slow moving whales, a pole delivery system is used similar to that developed by Moore *et al* (2001). Specifically, a 10-12 m pole is cantilevered from the bow of a small boat and allows tag attachment via suction cups from a greater distance than is typically possible with typical pole deployments. In some settings, for example with beaked whales or bow-riding dolphins, it may be simpler to hand hold a 2-4 m pole to deploy the tag. Baird successfully attached tags similar to the DTAG to porpoises in Puget Sound (Hanson and Baird 1998) and pilot whales in the Mediterranean (Baird et al. 2002) using this approach. The successful attachment of a DTAG to a beaked whale was achieved using this kind of short hand-held pole. In some settings, such as with larger, fast-moving toothed whales that do not bow-ride, it is preferable to use a cross bow to apply the tag remotely. Baird (1994) for example, has found the cross bow to be the best attachment method for killer whales. For cross bow attachments, the slight loss of precision in location of attachment is outweighed by the ability to rapidly attach the tag remotely from a greater distance. Dr. Tyack proposes to consider the cross bow as a potential fall back attachment method for suction cup tags. DTAGs are attached on the dorsal

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surface of the animal behind (caudal to) the blowhole and closer to the dorsal fin than to the blowhole. This tag placement ensures that the tag will not cover or obstruct the whale's blowhole. Even if the suction cup were to migrate along the whale's body after placement, the movement would be toward the tail (*i.e.*, further away from the blowhole) due to the forward motion of the whale.

The tagging protocol for each species will follow a general model, but will differ according to the size and shape of individual species and environmental conditions. Where possible, an observation vessel will track and observe the animal selected for tagging using visual and acoustic monitoring prior to tagging. This observed pre-tagging behavior may serve as a baseline and be compared to post-tagging behavior to indicate any effects of the tagging procedure. The tag attachment vessel will approach the animal as cautiously as possible while still achieving a position to allow attachment of the tag. During and after tag attachment, the observation and tracking vessel will track and observe the animal when it is at the surface for the duration of the tag attachment, as well as for a period post-tagging to ensure both that the data collected during the tag's life represent as normal a repertoire as possible and that the tag had no observable adverse effects on the animal. Either the tagging vessel or the observation vessel will recover the tag after it releases from the animal. Photos will be taken of all tagged animals, tagging attempts, and tag locations on the individual animals. Where applicable, the photos will be used to identify the tagged animal, *i.e.*, to compare to known catalogues for information about tagged individuals and to prevent duplicative tagging.

The tag can release from the animal in at least three ways. First, since the DTAG attaches with a suction cup, if an animal is bothered by the tag, the animal can dislodge it by rapid movements, by rubbing it on the seafloor, or by contact with another animal. Second, the tag can simply release on its own due to repeated diving (*i.e.*, pressure changes) working the suction cups loose, some other mechanical failure, or releasing with sloughed skin. Finally, there is a release mechanism that uses an electrically corrosive wire assembly to release the entire tag package (*i.e.*, DTAG, batteries, flotation, suction cups, plastic housing, and RF transmitter) from the

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whale. The corrosive wire assembly opens a tube to release the suction, and is not in contact with the whale at any time so it poses no threat. While working under Permit No. 981-1578 in the past few years, Dr. Tyack has repeatedly been able to obtain attachment durations of 4-12 hours on sperm whales, the maximum programmed recording time. The playback design (Projects 2 and 3) requires tags to be attached for about four to six hours, and the target attachment duration is 4-12 hours. Because the tag is attached behind the blowhole it has no chance of occluding the blowhole, since the tag migrates towards the tail as the animal moves.

### **2.2.2 Project 2: Tagging, playbacks of sperm whale codas, and tests of whale-finding sonar in the Mediterranean Sea**

Dr. Tyack proposes to use DTAGs to help calibrate measurements of the target strength (see footnote on page 6) of marine mammals as a function of their orientation in the water, and to validate the effectiveness of whale-finding sonars in detecting marine mammals. The whale-finder sonar being tested was developed by a NATO undersea research lab in Italy. The sonar uses a non-directional sound source and a sophisticated directional receiver. Dr. Tyack proposes to research to test how well this whale-finder detects whales in the Mediterranean Sea. DTAGs will also provide a sensitive tool to monitor potential reactions of marine mammals to the received sounds of the whale-finding sonars.

The main focus of the research will be sperm whales because they can be reliably tagged for long periods, they vocalize most of the time, can be tracked in real time, and as large whales, they should provide a strong echo signal for imaging through sonar. However there is a need for testing how well the sonar works for detecting the variety of species present in this area.

Therefore, for these tests Dr. Tyack proposes to tag any of a broad variety of species that may be encountered in this area, including fin whales, pilot whales, Risso's dolphin, bottlenose dolphins, common dolphins, and striped dolphins (Gannier 1998). Given the potential that beaked whales and possibly dwarf or pygmy sperm whales may be particularly sensitive to mid-frequency sounds, Dr. Tyack would not conduct any tests of the whale-finding sonars to those species, nor would he transmit anywhere within the beaked whale habitat identified in the Ligurian Sea.

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The whale-finding sonar source uses four elements mounted in a device that can be towed from a research vessel designed for acoustic research. The low-power sonar described in the current permit application from Dr. Tyack (Permit No. 981-1578) used source levels of 160-180 dB re 1  $\mu$ Pa at 1 m, and the permit was subsequently amended to use source levels of 160-200 dB re 1  $\mu$ Pa at 1 m. No echoes from whales were detected using these source levels, which has led Dr. Tyack to request an increase to the source level, but not the received level at the whale, which will remain 160 dB re 1  $\mu$ Pa at 1 m. The applicant proposes to increase the maximum source level to 210 dB re 1  $\mu$ Pa at 1 m. Given the frequency range of the sonar, even at the maximum source level of 210 dB, an animal as close as 30 m away would not be exposed to sound levels above 180 dB, and an animal as close as 317 m away would not be exposed to sound levels above 160 dB. The closest Dr. Tyack can typically approach a diving sperm whale is about 1000 m, so this source level would make it unlikely that the focal animal would be exposed to levels above 150 dB. The biological opinion written for Dr. Tyack's current permit (No. 981-1578) concluded that the proposed tagging and whale-finder sonar tests were not likely to affect the endangered blue, fin, humpback, sei or sperm whales in a way that reduces their reproduction, numbers, or distribution, and therefore, is not likely to appreciably reduce their likelihood of surviving or recovering in the wild.

The signals to be used for detecting marine mammals include a subset of the following for the mid-high frequency sonar:

Source levels: 160dB-210dB re 1  $\mu$ Pa rms at 1 m, not to exceed 160dB at the animal.

Signals: Chirp upsweeps centered at 1kHz, 2.5kHz, 4kHz, 8kHz, 12kHz.

Bandwidths: 100Hz, 200Hz, 400Hz.

Pulse Durations: 50ms, 100ms, 200ms, 400ms.

Pulse repetition: No more than 1 ping per 15 sec.

The pulses of the whale-finder sonar share some similarities with the clicks made by sperm whales, so Dr. Tyack proposes to use the natural click sounds of these animals as a control

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stimulus for evaluating behavioral responses of the whales to the sonar. For the control sounds, Dr. Tyack proposes to play back sperm whale coda signals, which are series of short (20-40 msec) clicks with a total duration not longer than a few seconds (Watkins and Schevill, 1977). The source level of these clicks is about 160-180 re 1  $\mu$ Pa at 1 m (Richardson et al. 1995, Table 7.2; Madsen et al. 2002), and we will limit the source level for coda playbacks to a maximum of 180 re 1  $\mu$ Pa at 1 m. Initially Dr. Tyack proposes to use a playback duration of a series of codas that may last up to several minutes. None of the playback signals last for longer than several tens of msec, and none will transmit clicks for more than % whatever the duration of transmission.

All operations and equipment associated with the application of DTAGs in Project 2 will be the same as in Project 1. The goal of the tagging component of Project 2 is to use DTAGs to measure the received sound level of transmissions at the animal, to measure the orientation and depth of the animal in order to assess variation in Target Strength (TS), and to measure any potential reactions of the tagged animals to sonar sounds. The DTAG has a three-axis magnetometer that can sense the orientation of the whale with respect to the earth's magnetic field. By comparing the whale's heading against the bearing from the ship to the whale with respect to ship's heading, it is possible to estimate the orientation of the whale to the sonar. Using data from the first cruises under Permit No. 981-1578, Zimmer *et al.* (2003) have validated the ability to link data from the tag on the whale to the sonar source on the ship to pinpoint the location and orientation of the whale. The hydrophone on the DTAG can also precisely measure Received Level (RL) of a sonar transmission at the tagged whale. If the Source Level (SL) of the transmission is known, then these data enable a precise calculation of Target Strength of the whale as a function of its orientation. Since Transmission Loss (TL) = SL – RL, measurement of SL and RL allows calculation of TL. The basic sonar equation is RL (back at sonar) = SL – 2 TL (round trip transmission loss) + TS. Therefore, if the SL is known and the RL is measured on the tag, the Target Strength can be calculated from the measurements on a ping-by-ping basis as a function of orientation.

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At the start of the cruise, an engineering test will be conducted to calibrate the sound sources. This is important to validate the models used to predict the received level of sound at the whale as a function of range and depth. For this preliminary test, Dr. Tyack will select an area with low density of marine mammals and an environment far from the beaked whale habitat. They will only start transmitting after monitoring visually and acoustically for 30 min with no detections of marine mammals. The source level will be ramped up starting at 162 dB re 1  $\mu$ Pa rms at 1 m, increasing by no more than 6 dB every two minutes. This two minute increment allows any whale or sea turtle as close as 1 m from the source plenty of time to swim away at 2 m/sec (a typical swim velocity for many species) to get beyond the 160 dB exposure range. If any marine mammals are detected within the 160 dB zone, corresponding to 317 m for the maximum source level of 210 dB (assuming spherical spreading), the source will be shut off until none are detected for 30 minutes again. Visual and acoustic monitoring will continue during the entire transmission period, and these monitors will have the source shutdown if any animal comes near the maximum exposure zone. The basic plan for this test is to use a buoy or boat to deploy a calibrated sonar target (not an active source, but test object with known reflectivity) and an array of calibrated hydrophones deployed vertically in the water. The source vessel then runs a pattern around the hydrophones. This allows the researchers to validate precisely how sound is propagating from the source to be used in the playbacks.

After the engineering test and validation, the research will switch to the protocol for playbacks. Early each morning the ship will use its passive hydrophone array and beamforming system to locate calls of marine mammals, with a primary focus on sperm whales. If calls are detected, the ship will move near the animals. Visual observers on both the playback vessel and the tracking vessel (if a separate tracking vessel is used) will start a lookout for animals as soon as sufficient daylight is available. If there are marine mammals in the vicinity, the ship will launch the tag attachment vessel once there is sufficient light to do so. The tagging vessel will primarily direct its efforts to sperm whales, but may attempt to tag whatever species are present. If beaked whales are sighted or tagged, no sounds will be transmitted. Otherwise, once an animal or several animals have been tagged and pre-exposure behavior recorded, the ship will maneuver

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within 2 km or so of the tagged animals and prepare to start transmitting sonar signals both to test the system's ability to detect whales and to evaluate possible reactions. The sound transmissions will follow the same controlled ramp up and observation protocols described for the source validation above. Transmissions will cease if there is any indication of an adverse behavioral reaction such as major deviations in direction of travel, rate of vocalizing or breathing, rapid and erratic breaching, or other observed changes in behavior (whether or not the maximum source level has been reached). Transmissions to a tagged animal will last for one to three hours. After this exposure period, the tagged animals will be followed at a distance to collect post-exposure data until the tag's release. If time allows, the process of searching for a new subject, attempting to tag, etc. would occur more than one time per day.

### **2.2.3 Project 3: DTAG and playback of coda vocalizations and sounds of airgun arrays to sperm whales in the Gulf of Mexico**

Dr. Tyack proposes a series of controlled exposure studies, or playback experiments, to resolve differences in results from earlier studies regarding the likelihood of sperm whales silencing, moving away, or showing other disruption of behavior when they are exposed to impulse sounds from an airgun array versus natural control sounds. These studies will involve visual observations of surfacing sperm whales, passive acoustic tracking of diving sperm whales, and tagging sperm whales with DTAGs.

A towed array composed of multiple airguns is the primary tool used by the oil and gas industry for exploring under the seabed for hydrocarbon deposits. In the Gulf of Mexico, these seismic surveys are very common; between 1998 and 2002, an average of 230,000 miles of surveying was conducted each year (MMS data). An individual airgun generates a sound with a level of 215-230 dB re 1  $\mu$ Pa p-p at 1 m, depending upon the size of the airgun (Richardson *et al.*, 1995; Table 6.6). The sound level within about 200m of a multiple airgun array is the most intense acoustic exposure an animal could receive. That level is equivalent to the contribution of the largest gun. Beyond 200m of the array, the sound level declines with distance. The source level of a full array of airguns is typically reported as being 250-265 dB re 1  $\mu$ Pa rms. Animals never

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experience these levels because of the way the source level estimate is made. Sound measurements are made at a distance of more than 200 m, and the results are extrapolated back to a hypothetical point 1 m from the array. No such point exists, so no animal could ever receive that level of exposure. Source levels that are estimated from a great distance (called far field measurements) are useful for comparing the propagation characteristics of different arrays, but they should not be used to estimate the maximum received levels for an animal. That level is equivalent to the array's largest gun.

While working under Permit No. 981-1578, Dr. Tyack recorded sound levels of 143 dB re 1  $\mu$ Pa rms at a range of 16 km and of 148 dB re 1  $\mu$ Pa rms at a range of 7 km from a 1680 cu. in. airgun array were recorded. This suggests that the received level 10 km away from the source would be about 145 dB re 1  $\mu$ Pa rms.

Dr. Tyack proposes to use two different kinds of sounds as playback stimuli in this project: impulse sounds from airguns and recorded sperm whale codas. Impulse sounds from airguns typically have peak energy below 100 Hz (Richardson *et al.* 1995), but the initial stages of the impulse have considerable energy at higher frequencies, even above 1 kHz (Goold and Fish 1998). Measurements of pulses from an airgun array recorded in previous research at shallow depths found significant energy at frequencies as high as 2-3 kHz. These impulse sounds share similarities with the clicks made by sperm whales, so it is useful to use the natural click sounds of these animals as a control stimulus. For the control sounds, Dr. Tyack proposes to play back sperm whale coda signals, which are a series of short (20-40 msec) clicks with a total duration not longer than a few seconds (Watkins and Schevill 1977). The researchers propose to initially use a playback duration of a series of codas that may last up to several minutes. Airguns typically broadcast one impulse every 10-15 seconds. None of the proposed playback signals lasts for longer than several tens of msec, and none will transmit pulses more than 1% of the duration of transmission (i.e., duty cycle<sup>5</sup>). Maximum received levels of the airgun array by the

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<sup>5</sup> Duty cycle is defined as the percent of the total time of the playback duration that sound energy is being emitted.

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whales will be 180 dB re 1  $\mu$ Pa.

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For airgun signals, Dr. Tyack proposes to use an individual airgun or an airgun array, but would prefer a full airgun array where possible, since that is the actual source used in commercial seismic surveying. Papers by Bowles *et al.* (1994) and Mate *et al.* (1994) suggest that sperm whales may react to airguns at ranges of 50-300 km. Richardson *et al.* (1995; fig 6.22) suggests that this would correspond to a received level of about 120 dB re 1  $\mu$ Pa, similar to the levels at which Watkins and Schevill (1975) observed responses to impulse sounds from pingers. If a single airgun with a source level of 220 dB re 1  $\mu$ Pa at 1 m was used, then this airgun could easily achieve this received level at a range of 10 km or more. Dr. Tyack states that, in his experience, it is difficult to maneuver a source vessel closer than 1 km from tagged whales, and coming any closer makes it more difficult to predict range and therefore exposure. If sperm whales show little response to the lower end of exposures and the vessel cannot approach closer than 1000 m from the subject, then an airgun array (rather than a single airgun) would be required to produce sound level necessary to test responses to received levels near 180 dB re 1  $\mu$ Pa rms.

At the start of the cruise, an engineering and calibration test to calibrate the airgun(s) will be conducted. This is important to validate the models used to predict the received level of sound at the whale as a function of range and depth. For this preliminary engineering and calibration test, the researchers will select an area with low density of marine mammals in a habitat where beaked whales would not be expected. Transmissions will only start after monitoring visually and with passive acoustics for 30 min with no detections of marine mammals. The source level will be ramped up by no more than 6 dB every five minutes. This five minute interval is usually used for ramp up of seismic airguns. If any marine mammals or sea turtles are detected within the 180 dB zone, corresponding to 300-500 m distance from the sound source, for the maximum source level of 230 dB viewed with horizontal displacement, the source will be shut off until none are detected for 30 minutes again. The basic plan for this test is to use a buoy or boat to deploy an array of calibrated hydrophones vertically in the water, then for the source vessel to

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run a pattern around the hydrophones. This allows the researchers to validate precisely how sound is propagating from the source to be used in the playbacks.

Dr. Tyack's proposed playback protocol is designed to test responses to exposures that mimic the different ways in which a sperm whale may be exposed to a commercial seismic survey (*e.g.*, hearing an airgun array operating at some range and low levels for quite a while; hearing a steady increase when a seismic ship approaches; and more rarely, if near a vessel at startup, it would hear the normal ramp up procedure, in which the vessel roughly doubled the sound energy, by increasing the number of airguns firing, every five or so minutes)

The playback will start with a soft start ramp up procedure at a distance where the received level is well below the goal for maximum received level for the playback (*i.e.*, 180 dB re 1  $\mu$ Pa rms). Sounds will only be transmitted following a careful procedure. Visual and passive acoustic monitors will work for half an hour to see if any animals might be within the maximum exposure zone (*i.e.*, the zone where the received level would be at or above 180 dB re 1  $\mu$ Pa rms). If no marine mammals or sea turtles are detected near this zone during the 30 minutes, a single airgun will begin operating, and the source level will be increased by adding more airguns firing every 5 minutes until it reaches the maximum planned level involving the full airgun array. The ramp up procedure for the airgun array uses a longer interval for doubling than the whale-finding sonar (Project 2), because this is the standard interval used by seismic industry, and Dr. Tyack wishes to be able to use possible responses of whales to the ramp up sounds to infer effects of the industry protocol. Using a longer time interval between sound increases for this more intense source also increases the distance and time over which animals could choose to avoid the sound by swimming away. Then the source vessel moves on as straight a course as possible to pass by the whales at a range for a closest point of approach corresponding to the goal maximum received level for the playback. The direction from which the source vessel approaches is organized so that the tagged whale(s) are those closest to the sound source if there are more whales present than those tagged. Visual and acoustic monitoring will continue during the entire transmission period, and these monitors will have the source shut down if any animal comes near

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the maximum allowed exposure zone.

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The proposed playback protocol is designed to minimize chances of inadvertently exposing animals to levels above the maximum planned exposure level. The range for an array that would likely be used for playback experiments would have the 180 dB range (isopleth) at a horizontal displacement less than 1 km from the source vessel. Thus the highest planned exposures would involve passing the target animal at a horizontal range of about 1 km. In order to predict exposure to whales at or above the 160 dB re 1  $\mu$ Pa rms region, when the source vessel must come within nearly a kilometer from the whale, Dr. Tyack needs sophisticated acoustic modeling, tested and validated by measurements of sound made near an airgun array. The researchers are collaborating with ocean acousticians and experts in propagation from airgun arrays to develop this model, which will be operated on the ship at sea. The model will be validated by the calibration test and its predictions will be checked after each playback once received level data are downloaded from the tag. Playbacks will only be conducted in conditions of good visibility, with a constant watch of at least two visual observers for at least half an hour before the playback, and while using passive acoustic monitoring for cetacean vocalizations using a towed hydrophone array. By measuring the time delay between the direct path and surface reflection of sperm whale clicks, the researchers have been able to estimate range quite accurately to diving sperm whales when they are clicking (Thode *et al.* 2002).

The tagged subject playback protocol is as follows. Focal whale subjects will be tracked using visual observation, passive acoustic tracking, and sighting of DTAGs and monitoring the radio transmitter on the DTAGs when possible. Once a whale is tagged and photo-identified by the tagging vessel and the tag is secure on the whale (see below for kinds of data recorded during tagging attempts), it will be identified as a focal animal. At least one full surfacing and dive sequence will be monitored before playback starts. If the focal whale is not engaging in long dives, a pre-exposure period of 40-60 min will be conducted before any playbacks begin. The researchers will attempt to have whale observers and tag trackers blind to the playback timing and condition. Playbacks will be conducted with the playback (source) vessel moving towards

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the focal whale at a speed of about 3-8 km/hr. Typical speeds for commercial seismic vessels are 5-9 km/hr; the observation vessel will typically operate within this speed range. If the playback vessel approaches the tagged whale from a range of 10 km, this would yield an approach interval of just over an hour at the 8 km/hr speed. The playback vessel will plan its approach to pass within a predetermined distance from the whale(s), then pass the whale(s) before ceasing the playback. Every attempt will be made to monitor the behavior of the tagged whale for at least 40-60 min post-approach.

A critical element of the design of the experiments is to have roughly equal data sets on the behavior of the tagged whale before, during, and after playback. This allows each individual whale's pre-playback behavior to serve as its own control. This is critical for cases where behavior of one individual may be quite consistent over several hours, but may differ from other individuals at other times and places. Dr. Tyack often obtains tag retention times of 6-12 hours, allowing for two pre-exposure dives over two hours, two exposure dives over two hours, and at least two hours of post-exposure observations. If responses are seen, Dr. Tyack will design later tests to optimize chances for observing complete return to baseline (*i.e.*, pre-tagging/playback) behavior.

All operations and equipment associated with the application of DTAGs will be the same for Project 3 as in Project 1.

### **2.3 Mitigation measures**

Dr. Tyack has included many mitigating measures into the research design and operational protocols that will help to minimize any negative impact of the research on the animals. A number of data collection capabilities are planned for the research, to include visual monitoring, passive acoustics, and separate vessels for observing the subjects and for transmitting sound. These data collection systems have the capacity to detect potentially adverse or acute reactions of marine species. The objective of the mitigation measures outlined in this section is to ensure avoidance of injury to marine mammals and sea turtles in the immediate vicinity of the sound

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source, and of human divers in the near shore environment. These particular measures include manipulation of the sound level, repositioning of the source geographically or in depth, and gradual increase of the goal Received Level at the subject. Both the equipment capabilities and these procedures serve the dual role of aiding in minimizing any potential adverse impact while preserving the primary objectives of the research.

### **2.3.1 Mitigation during tagging and close approach operations**

Animals need to be approached to within 10 m for tag attachment. This will be done in a way to minimize disruption: slowly, deliberately, and for as short a time as possible. During close approaches for tagging, some animals may show avoidance reactions. If an animal shows a strong attempt to avoid the approaching tagging vessel, the researchers will break off the approach and select a different subject. If after three approaches they are not able to attach a tag, a different subject for tagging will be selected.

The DTAG is constructed to minimize the effect of the tag on the animal. The tag is non-invasive as it is attached using a suction cup. If an animal is bothered by the tag, the animal can remove it by maneuvering rapidly, by breaching, or by rubbing the tag off on a solid surface like the seafloor or another animal. Because the tag is attached behind the blowhole it has no chance of threatening the health of the animal, because, if the tag migrates, it would move toward the tail as the animal moves.

### **2.3.2 Mitigation during playback operations**

#### Visual Observations

Marine mammal biologists qualified in conducting at-sea marine mammal visual observations will maintain a topside watch and a marine animal observation log onboard the playback vessel during the proposed research operations. The objective of these observations is to visually track any animals within at least one km and to ensure that no animal approaches the source close enough to be subjected to potentially harmful sound levels. Under conditions of normal visibility, the field of visual observation is approximately 3 nm (5.6 km) from the source.

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Observations from a minimum of 2 observers will begin at least one half hour prior to initial transmissions. The visual observation and monitoring watch will be maintained throughout the period of transmission and for 30 minutes thereafter. Once transmissions have commenced, they will be suspended if animals are observed demonstrating significant behavioral modification. Examples of such behavioral modification would include major deviations from the direction of travel, rate of vocalizing or breathing, or other observed changes in behavior pattern. With respect to non-focal animals, particularly other whales, transmissions would be suspended if in the opinion of the principal investigator, the animals are demonstrating exaggerated behavior, rapid and erratic breaching, and extended surface periods, possibly contemporaneous with sound transmissions. This mitigation procedure involves visual observation of both the port and starboard sides of the source vessel for full coverage. Visual monitoring, within daylight visibility constraints, will be in effect throughout the entire course of all experiments and phases, as no night time operations are planned.

**Passive acoustic monitoring**

Hydrophones will be employed during the proposed experiments for passive acoustic monitoring, (*i.e.*, tracking detecting/tracking animals based on their vocalizations). Acoustic monitoring will be important for following the behavior of deep diving animals such as sperm whales that vocalize throughout most dives, and where cessation of vocalization could provide evidence of a disturbance reaction. However, passive acoustic monitoring is only effective for detecting vocalizing animals and for mitigation purposes; such monitoring will not play as large a role in these experiments as the visual monitoring.

**Ship repositioning**

The planned conduct of the research permits flexibility in locating and repositioning the ship to optimize the research data collection effort, while altering the source-receiver (vessel-animal) geometry to minimize potential adverse effects. Repositioning the ship also allows control of the sound level being introduced into areas of concern or away from non-tagged animals that may be incidentally exposed to the playbacks.

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Initiation, sequencing, and duration of transmissions

The researchers plan to start playbacks of a specific signal to a focal animal at the lowest received levels thought to pose a risk of behavioral disruption. Both the whale-finding sonar and the airgun will be ramped up at the beginning of the exposure. This gradual increase is designed to allow ample time for any marine animal in the vicinity to move away from the sound source if they react negatively to the sound level.

The researchers will only increase the exposure level after determining a low risk of disruption at the lower level. The design of these studies (*i.e.*, to test whether specific acoustic exposures cause behavioral disruption) does not necessarily mean that they must continue increasing exposure until they detect disturbance. Few of these studies would be able to detect hearing effects such as temporary threshold shifts (TTS), so even if the researchers have not detected behavioral disruption, they will limit exposure to levels below those thought to pose a risk of TTS.

If evidence of a disturbance reaction during a playback is observed, researchers will not increase the received level at the subject. The researchers will continue to follow the focal animal and will monitor how long it takes the animal to return to baseline behavior. If there is any sign of prolonged responses that might pose a risk of physiological stress or risk of injury, the researchers will stop the playback, and will communicate with the OPR of the NOAA Fisheries. Dr. Tyack states that he would confer with NOAA Fisheries OPR to develop a protocol to ensure that future playbacks would limit exposure to levels below those likely to expose animals to any such risk.

Playbacks will last on the order of 1-3 hours to test whether disrupted behavior may soon resume even during exposure, and the researchers plan to follow post-exposure behavior carefully to monitor how long it may take to return to baseline. In the past few years Dr. Tyack has achieved 12 hour tag attachments, a duration that allows data collection for a 3 hour pre-exposure period,

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3 hour exposure and up to 6 hours post exposure.

#### Species exceptions

Because of the apparent heightened sensitivity of beaked whales to sonar, for playbacks under project 2 in the Mediterranean, Dr. Tyack will not conduct playbacks to the genus *Kogia* and beaked whales of the species *Ziphius cavirostris* and *Mesoplodon densirostris*. The researchers plan to avoid known *Ziphius* habitat, which is well studied in this region, monitor carefully for these species, and shutdown if any are sighted at any range from the source vessel. Therefore, the combination of lower source level, selection of location, and monitoring and mitigation measures reduce the odds of any incidental harassment takes for these species in Project 2 to as low as possible, with an extremely low possibility of lethal take.

During Project 3, if any animals other than the sperm whale subjects of the experiment are detected and judged to be at risk of coming within the range corresponding to the maximum 180 dB exposure level during ramp up, the researchers will postpone the start of playback until these animals are outside the maximum exposure zone. Visual and acoustic monitoring will continue during the entire transmission period, and these monitors will have the source shutdown if any animal comes near the maximum exposure zone. The researchers will position the playback vessel to be closer to the tagged whale(s), which are the focal subjects, than other sperm whales that may be in the area, and will conduct approaches so as to minimize closer approach to other whales.

#### Maximum received level for controlled exposures of noise

The most important criterion for the selection of the maximum exposure factors (received level and duration) that animals will experience, involves concern to not expose animals to sounds that might cause physiological harm or injury. The range of sound exposures selected is based on NOAA Fisheries belief that these levels are unlikely to pose an adverse impact. New evidence suggests that these previous guidelines are very conservative. Dr. Tyack advocates using TTS as a signpost indicating that exposures below those levels that cause TTS are likely to be safe in the sense that they will not cause injury. The primary features the researchers will control in the

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experiments are the duration and received level of sound at the test subject, and they will model or measure sound propagation in order to predict and control exposure at the animal. Dr. Tyack has established a maximum combination of received level and duration above which they will not expose animals in order to avoid exposures that might enter the range of possible harm to the auditory system. For exposure to brief impulses from airguns, and short sonar signals with low duty cycles of the sort to be tested in these studies, the TTS studies suggest that a maximum exposure level of 180 dB re 1  $\mu$ Pa is highly conservative. No adverse impacts were observed during the three years of research conducted under Permit No. 981-1578, nor other playback experiments with sperm whales using similar stimuli (Gordon *et al.* 1996). The behavioral reaction most commonly reported for sperm whales exposed to brief manmade sounds is cessation of vocalization (Watkins *et al.* 1985; Bowles *et al.* 1994). This vocal behavior will be monitored in real-time, and playbacks will cease if whales stop vocalizing so that researchers can determine how long it takes the whales to return to baseline vocal behavior.

## **2.4 Alternatives considered but eliminated from detailed study**

Another alternative would allow the proposed research to be authorized but with reduced sound levels. For Project 2, Dr. Tyack has requested a source level of 160-210 dB re 1  $\mu$ Pa at 1 m for the whale-finding sonar, with received levels not to exceed 160 dB at the animal. An alternative to the Proposed Action, would be to allow Dr. Tyack to perform the research outlined in Project 2, but with lower source levels (*e.g.*, 160-180dB). However, under his current permit (981-1578) Dr. Tyack tested this same whale-finding sonar first with source levels of 160-180 dB re 1  $\mu$ Pa at 1 m, and subsequently using source levels of 160-200 dB re 1  $\mu$ Pa at 1 m. In these experiments, no echoes of the whale's shape were received. To be useful as a mitigation tool, the whale-finding sonar must be able to detect the sound echoes bouncing off the whale's body, just as a fish finder shows a display of where the fish are located. Since no echoes were obtained at the lower dB levels, a higher source level is required to continue testing the whale-finding sonar. Therefore, this alternative was eliminated from further consideration since continuing to use lower source levels that have been shown to be unsuccessful would not meet the objectives of

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this research to develop a tool for detecting animals underwater.

An alternative to the controlled airgun experiments outlined in Project 3 would be to collect data by examining the seismic surveying already taking place in the environment by the oil and gas industry. This alternative would allow Dr. Tyack to study animals near seismic activity, but not to conduct his own playbacks of airgun impulses. Unfortunately, studies like this have many inherent problems and even with good cooperation from industry, carefully planned studies have generally yielded inconclusive results (Richardson *et al.*, 1987). Studies attempting to correlate intensity of seismic activities with obvious biological measures such as distribution of animals or marine mammal strandings are difficult. Since they rely on the timing and location of industry activities, these studies usually lack geographical replication and control data from undisturbed areas. It is also difficult in an uncontrolled experiment to discriminate whether behavioral changes are due to naturally occurring or experimental variables. Because industry, not the biologists, control the sound source, it is often difficult to obtain pre-exposure, exposure, and post-exposure data from the same individual animals (Green *et al.*, 1994; Popper *et al.*, 2000). This data is important since behavior may vary by individual. Ongoing active sound operations may also bias the pool of potential subjects for studies. The animals remaining in an area where intense sound sources have been operated for a long time may be a subset of the population that for some reason does not avoid the sounds (*e.g.*, have habituated to the sound, are more strongly attracted to the area for food, mates, etc.). This alternative does not allow for an experimental design where the received level, location, and targeted animal can be controlled by the researcher. Adequate behavioral data necessary for determining responses of the animals to the sound source could not be obtained. Furthermore, similar projects have been attempted with inconclusive results. This alternative was eliminated from further examination since it is not considered a viable way of obtaining unbiased scientific data on responses of marine mammals to airgun impulses.

### **CHAPTER 3 AFFECTED ENVIRONMENT**

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This chapter presents baseline information necessary for consideration of the alternatives, and describes the resources that might be affected by the alternatives, as well as environmental components that would affect the alternatives if they were to be implemented. The effects of the alternatives are discussed in Chapter 4.

### **North Atlantic Ocean**

For the purposes of the proposed action, the North Atlantic Ocean is considered separate from the Arctic Ocean. Thus, the northern boundary of the North Atlantic Ocean is defined by drawing a line eastward from Greenland to Iceland along the shallow Greenland-Iceland Rise and from Iceland to the Faroe Islands along the Faroe-Iceland Rise and then northward from the Faroes along the relatively shallow bottom features of the Voring Plateau to the west coast of Norway at a point near 70° N. With its areas of relatively broad continental shelf, proportionally large runoff from land, and patterns of water circulation, the North Atlantic is home to a large variety of seaweeds, most notably the huge masses of gulfweed (*Sargassum natans*) in the Sargasso Sea that support large communities of crustaceans and fish normally associated with coastal regions and that are the spawning grounds for the American and European freshwater eels of the genus *Anguilla*. The areas of coastal upwelling of cold, nutrient-rich deep water are the sites of large plankton blooms, which, in turn, are the basis of much of the North Atlantic's rich fish life. In addition to fish, the North Atlantic is home to a variety of sponges, mollusks, and sea turtles. Coral reefs are confined largely to the Caribbean and do not approach those of the Pacific in the diversity of their reef life. Dolphins, whales, manatees, and pinnipeds are also found in various areas of the North Atlantic.

The Atlantic's major fishing grounds – representing more than half the world's total - continue to provide millions of tons of fish annually for human consumption and industrial purposes. Most of the Atlantic fish catch is taken from waters of the continental shelf, primarily from the nutrient-rich areas of upwelling. Haddock, cod, lobster, mackerel, menhaden, shrimp, shellfish, and eels are among the more important commercial fish taken in the North Atlantic.

There is a wealth of petroleum and natural gas beneath the continental shelves and slopes and the

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oceanic rises and plateaus of the Atlantic basin proper and portions of its marginal seas.

Estimates of the amounts of recoverable reserves have ranged as high as one-fourth to one-third of the projected total for all of the world's recoverable oil and natural gas, representing the vast majority of all of the Atlantic's nonrenewable resources. In the United States, revenues from offshore leases have been one of the largest sources of federal income, and receipts from offshore production have been important for the economies of the United Kingdom and Norway since the 1970s.

Extensive mining of sand, gravel, and shell deposits in shallow parts of the continental shelf takes place off the coasts of the United States and Britain. The recovered aggregates are used as landfill, for construction, and for making concrete. Sulfur is recovered from the floor of the Gulf of Mexico off Louisiana.

As coastal populations along the Atlantic and its marginal seas have grown - particularly in Europe and North America - there has been substantial growth in such recreational activities as sport fishing, sailing and cruising, wind surfing, and whale watching. Many of these activities compete for space and community support with traditional commercial marine activities, including fishing and shipping. For example, sport fishing now constitutes a significant portion of the total marine catch in the west-central Atlantic and is thought to be threatening the populations of some commercial species. The economic livelihood of much of the Caribbean basin, Bermuda, the Florida Keys, and the French Riviera is tied closely to their tourist and recreational industries.

### **Mediterranean Sea**

The Mediterranean Sea covers 2,500,000 square kilometers with an average depth of 1,500 meters. The coastline of this Sea extends 46,000 kilometers through 22 countries. Demographic trends in the Mediterranean Sea provide the foundation for major concern about the environmental future of the region. Today, about 82 million people live in coastal cities in the Mediterranean Sea; by 2025, that population is projected to increase to 150-170 million people (WWF 1999).

The size of this human population has left its footprint on the ecology of the Mediterranean Sea. About 70 percent of the wastewater discharged into the Mediterranean Sea is untreated. About 650,000 tons of crude oil are released into the Mediterranean Sea annually from various sources. Other pollutants reach the Mediterranean Sea from its major river systems: the Rhone, the Nile, and Po, and the Ebro, which discharge high levels of agricultural and industrial waste into the Mediterranean Sea. Because the Mediterranean Sea is almost entirely landlocked and has a low renewal rate (between 80 and 90 years), water pollution poses a serious threat to its health and ecology.

Cetacean populations are reportedly declining in the Mediterranean Sea because of the combined effects of habitat degradation, large-scale pelagic driftnet fisheries, severe water pollution, disturbance from intense marine traffic, and direct takes and intentional harassment. Habitat degradation threatens to worsen with increasing tourism along the coast of the Mediterranean Sea. Environmental noise from mineral prospecting (airgun) and military operations is another source of concern.

### **3.1 Sanctuaries**

#### *Ligurian Sea Cetacean Sanctuary*

In 1989, the Tethys Research Institute proposed creating a cetacean sanctuary in the international waters of the Ligurian Sea. In March 1993, the governments of Italy, France, and Monaco met in Brussels and signed a joint declaration for the creation of a Mediterranean Sanctuary for Marine Mammals. The proposal called for the creation of an international protected area for cetaceans in the Mediterranean Sea located between the continental coast of Italy, Monaco, and France, Corsica, and Sardinia. In September 1998, the government of Italy signed an agreement to create the Ligurian Sea Cetacean Sanctuary, which is now being considered by the governments of France and the Principality of Monaco. On 25 November 1999, the governments of Italy, France and Monaco established an international area for protecting cetaceans in the Mediterranean Sea, between Italy, Monaco and France, Corsica and northern Sardinia. Eight cetacean species are regularly sighted there. The most common species are

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striped dolphins and large numbers of fin whales that congregate there during summer to feed. Cetacean populations in the Mediterranean Sea are impacted by habitat degradation and fisheries. The concept of creating an area to minimize these impacts in an area of the Mediterranean was first proposed in 1989 by the Tethys Research Institute, a non-profit non-governmental organization. In March 1993, the governments of Italy, France and Monaco signed a joint Declaration for the Creation of a Mediterranean Sanctuary for Marine Mammals. This was finally enacted in November 1999.

The proposed research would offer some help in developing a method that may reduce the risk of vessel collision in this Sanctuary. The vessel traffic in the Ligurian Sea is already high and there is increasing use of high-speed ferries, which pose a risk of collision to marine mammals. The research would test low-power, mid-high frequency sonar for detecting whales and dolphins. The sonar is being developed as a monitoring tool to reduce the risk that marine mammals may be exposed to adverse sound levels. This kind of sonar may in the future be used by ships to detect and avoid submerged marine mammals. The research proposed here would also test whether exposures to these low-power sonar sounds evoke any behavioral reaction from marine mammals.

#### *Flower Garden Banks National Marine Sanctuary*

Designated as the country's tenth national marine sanctuary by NOAA in January 1992, the Flower Garden Banks National Marine Sanctuary is located 120 miles southeast of Galveston, Texas, in the Gulf of Mexico. The sanctuary was originally composed of a pair of submarine banks located 12 miles apart that rise from depths of 328 feet to crest in water depth of only 60 feet. The banks are topped by assemblages of reef-building corals and associated tropical and sub-tropical organisms. The relatively low diversity reef covers nearly 300 acres at the East bank and 100 acres at the West bank. An additional reef, Stetson Bank, was added to the sanctuary in 1996. A wide array of marine life, including numerous species of rays and sharks, sea turtles, and marine mammals, frequent the shallow, warm waters of the Gulf. Over 170 species of fish and approximately 300 species of reef invertebrates inhabit the banks. The

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colorful coral reefs of the Flower Gardens and the marine life associated with them are unique for their location, as they are the northern most coral reefs on the continental shelf of North America.

As a National Marine Sanctuary, certain activities within and near the Flower Gardens are regulated, such as: injuring, removing, possessing, or attempting to injure or remove living or non-living resources; feeding fish and certain methods of taking fish; vessel anchoring and mooring; discharging or depositing polluting materials within or near the Sanctuary; altering the seabed or constructing, placing or abandoning any structure or material on the seabed; and exploring for, developing, or producing oil, gas or minerals within the "No Activity Zone" established by the Minerals Management Service

Although the Flower Garden Banks National Marine Sanctuary is located in the Gulf of Mexico, Dr. Tyack does not plan to conduct any of the activities associated with Project 1 or Project 3 in or near sanctuary waters (Project 2 is limited to the Mediterranean Sea). Therefore no impact to the sanctuary is expected from the proposed research.

#### *Other marine sanctuaries*

Although the action area for Project 1 encompasses the North Atlantic and for Project 3 the Gulf of Mexico, Dr. Tyack does not currently (?) plan to conduct any of the proposed research activities within a national marine sanctuary. However, all scientific research permits issued by NOAA Fisheries include a condition that states that the applicant must have any and all other federal, state, and local permits that may be required to work in their study area. If Alternative 2 was selected and the proposed research was authorized, Dr. Tyack's permit would be conditioned so that if he wished to work within a national marine sanctuary he would have to obtain the proper permit from that sanctuary.

### **3.2 Marine Species**

The proposed research involves takes of many different cetacean species, both endangered and

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non-endangered. In addition to the cetacean species that are the focus of the proposed research, the action area (North Atlantic, including the Gulf of Mexico and the Mediterranean Sea) is inhabited by numerous other marine species including pinnipeds, fish and invertebrates, sea turtle, sharks, and seabirds. This section discusses the distribution, abundance and general life history of the marine mammals and other sea life that may be potentially encountered during the proposed research.

### **Minke Whale (*Balenoptera acutostrata*)**

Minke whales occur in all oceans. The minke whale is not listed as endangered under the Endangered Species Act, but it is protected under the Marine Mammal Protection Act. Four stocks have been described for the North Atlantic: Canadian east coast, west Greenland, central North Atlantic, and northeastern North Atlantic (Donovan 1991). However, Donovan (1991) also quotes the following conclusion from the IWC scientific committee: "The evidence for dividing minke whales in the North Atlantic into different stocks is very scanty." The IWC estimates a population size for the North Atlantic, excluding the Canadian East Coast, of approximately 149,000 (95% confidence estimates 120,000-182,000). The current best estimate of the Canadian east coast stock is 4,018 with a minimum of 3,515 (Waring *et al.* 2001). The potential biological removal (PBR)<sup>6</sup> is estimated at 35. AUTECH (2000) list minke whales in their checklist of cetaceans sighted in Bahamian waters, but the sighting probability is listed as low. Minke whales have been sighted in the Gulf of Mexico (Jefferson and Shiro, 1997), but were not sighted routinely enough to allow calculation of abundance by Davis *et al.* (2000). Notarbartolo di Sciara and Demma (1997) list minke whales as occasionally sighted in the Mediterranean. Minke whales may be selected for tagging in Project 1 in the Mediterranean and/or North Atlantic and may be exposed to sound playback as part of the permitted research in Project 2 in the Mediterranean. There is a small chance that they may be incidentally exposed to sound playback in the Gulf of Mexico as part of Project 3.

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<sup>6</sup> Potential Biological Removal (PBR) level is defined as the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing the stock to reach or maintain its optimum sustainable population.

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**Bryde's whale (*Balaenoptera edeni*)**

Bryde's whales are not listed as endangered under the Endangered Species Act. The distribution of Bryde's whales is tropical, typically less than 35 degrees of latitude. Bryde's whales are the most common baleen whale in the Gulf of Mexico and are the only mysticete species routinely sighted there. Mullin and Hoggard (2000) report that Bryde's whales are sighted in groups of up to seven in the Gulf of Mexico. Davis *et al.* (2000) did sight them often enough in the northern Gulf of Mexico to estimate an abundance of 35, but they were among the least commonly sighted species overall. Bryde's whales are in the checklist for the Canary Islands (Carillo N.D.) and they might be sighted during tagging cruises in the western North Atlantic, so they may be tagged as part of Project 1. Bryde's whales are not in the checklist for the Mediterranean (Notarbartolo di Sciara and Demma 1997). Thus it is unlikely that Bryde's whales will be exposed to playbacks or that the researchers will have an opportunity to tag them as part of Project 2. Due to their occurrence in the Gulf of Mexico, Bryde's whales are listed for Project 3 in the very unlikely event that one might unintentionally be exposed to playback.

**Beaked whales (*Mesoplodon* spp)**

Beaked whale species are difficult to identify at sea; therefore, most field identifications are made at the generic level at best (Mead, 1989b; Waring *et al.*, 1999). Beaked whales known to inhabit the North Atlantic include the northern bottlenose whale (*Hyperoodon ampullatus*), Cuvier's beaked whale (*Ziphius cavirostris*), and four species of mesoplodonts –Sowerby's beaked whale (*Mesoplodon bidens*), Blainville's beaked whale (*M. densirostris*), Gervais' beaked whale (*M. europaeus*), and True's beaked whale (*M. mirus*). Data on stocks of all mesoplodont whales and Cuvier's beaked whale have been combined into a single category for "undifferentiated beaked whale" in NOAA Fisheries U.S. Atlantic Marine Mammal Stock Assessments – 1998 (Waring, *et al.*, 1999). Stock structure for all mesoplodonts in the North Atlantic and Mediterranean is unknown. Most data on the distribution of species are obtained principally from stranding records; however, sightings data have also been obtained from NOAA Fisheries survey cruises in the western North Atlantic near Georges Bank and in the Gulf Stream (Mead, 1989b; Smithsonian Institution cetacean distributional database, unpublished data, 1999;

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Waring *et al.*, 1999). Sowerby's beaked whales have been reported from New England waters to the ice pack, and along the Newfoundland coast in the summer. Both Blainville's beaked whale and Gervais' beaked whale tend to be distributed in tropical to warm-temperate waters, and have been reported from the Gulf of Mexico, Caribbean, and Florida with northernmost strandings for each species occurring off Nova Scotia and Massachusetts, respectively. Reiner *et al.* (1993) report strandings of Gervais' beaked whales and Cuvier's beaked whales in the Azores Islands, and Sowerby's beaked whale is sighted there. In the Canaries Islands, Blainville's beaked whales and Gervais' beaked whales have been sighted, and there is one stranding record for True's beaked whale (Carillo N.D.). Stranding records for True's beaked whales range from the Bahamas to Nova Scotia, and it is considered to be a temperate water species.

The beaked whales reported in the Mediterranean include Cuvier's and Blainville's beaked whales. Little is known about the abundance of either species in the Mediterranean. Both species are also known from the North Atlantic, but it is not known whether the populations of these beaked whale species are isolated for these two areas.

The total number of mesoplodont beaked whales and Cuvier's beaked whales in the North Atlantic is unknown, and it is impossible to determine the minimum population estimate of either taxon (Waring *et al.*, 1999). The best estimate of abundance for the undifferentiated beaked whales is 1,519 (CV = 0.69) from data obtained during NOAA Fisheries line transect surveys conducted during July to September, 1995 (Waring *et al.*, 1999). These surveys provided the most thorough coverage to date of known deep-water habitats preferred by beaked whales. The minimum population estimate for undifferentiated beaked whales is 895 (CV = 0.69); however, neither estimate includes a correction factor for submerged animals (Waring, *et al.*, 1999). There are insufficient data to determine population trends, and current and maximum net productivity rates are unknown. PBR for the undifferentiated beaked whale complex is 8.9; the total average estimated annual fishery-related mortality of beaked whales in the U.S. Exclusive Economic Zone (EEZ) for 1992 - 1996 was 9.7 (CV = 0.07) (Waring *et al.*, 1999).

The status of both mesoplodont beaked whales and Cuvier's beaked whales relative to the optimum sustainable population in the U.S. Atlantic EEZ is unknown (Waring *et al.*, 1999). Neither group is listed as threatened or endangered under the Endangered Species Act. PBR

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cannot be determined at the species level; however, the total fishery mortality and serious injury for this group exceeds the calculated PBR, thus it cannot be considered to be insignificant and approaching zero mortality and serious injury rate for undifferentiated beaked whales (Waring *et al.*, 1999). Because of uncertainty regarding stock size and evidence of U.S. fishery-related mortality and serious injury, both Cuvier's beaked whales and mesoplodont beaked whales are considered to be strategic<sup>7</sup> stocks by NOAA Fisheries (Waring *et al.*, 1999). In addition to the fisheries mortality, there is increasing evidence that unusual mass strandings of beaked whales are related to naval maneuvers involving high-power, mid frequency sonars (Evans and England 2001). The extent of mortality and injury caused by this is unknown. Similar strandings are reported for beaked whales in the Mediterranean (Frantzis 1998; D'Amico 1998) and eastern North Atlantic (Simmonds and Lopez-Jurado) 1991. Beaked whales will be tagged to study baseline behavior as part of Project 1. Because of their evident special sensitivity to sound, they will not be subjects for playback experiments in Projects 2 and 3, and Dr. Tyack will make every effort to not incidentally expose them to playback sounds.

#### **Cuvier's beaked whale (*Ziphius cavirostris*)**

Heyning (1989) suggests that Cuvier's beaked whale may have the widest distribution of any beaked whale and Würsig *et al.* (2000) suggest that their distribution is limited to between 60° N and 50° S. Strandings of Cuvier's beaked whales near the east coast of the US have occurred from Nova Scotia to Florida, Gulf of Mexico, and the Caribbean, with sightings primarily occurring along the continental shelf edge in the mid-Atlantic. Cuvier's beaked whales are observed in the Mediterranean, but little is known about their abundance and it is unknown whether the population in the Mediterranean is isolated from that in the Atlantic. Cuvier's beaked whale is present in the Gulf of Mexico, with an estimated abundance in the oceanic northern Gulf of Mexico of 159 animals (Davis *et al.* 2000). Mullin and Hoggard (2000) report that Cuvier's beaked whales tend to be sighted along the deep continental slope at depths of

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<sup>7</sup> A strategic stock is defined by the MMPA as a marine mammal stock: a) for which the level of direct human-caused mortality exceeds the potential biological removal (PBR), b) which, based on the best available scientific information, is declining and is likely to be listed as a threatened species under the ESA within the foreseeable future; or c) which is listed as a threatened species or endangered species under the ESA, or is listed as depleted

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about 2000 m in groups of 1-4. See the section above for information that combines Cuvier's beaked whales with other "unidentified beaked whales."

There has been growing concern that beaked whales in general, and Cuvier's beaked whales in particular, may be particularly sensitive to intense sounds from high power mid-frequency sonars (Evans and England 2001). There is growing evidence for a correlation between mass strandings of beaked whales including Cuvier's beaked whales and mesoplodont beaked whales with naval maneuvers involving ships that have hull-mounted high power mid-frequency sonar systems (Simmonds and Lopez-Jurado 1991; Frantzis 1998; D'Amico 1998). Some of the research covered by Project 1 involves studying the distribution, behavior, and vocalizations of beaked whales in order to better understand factors that might lead to their acoustic sensitivity, and be able to better detect them. In light of their potential vulnerability to acoustic stimulation, the proposed research for playbacks or transmission of sounds in Projects 2 and 3 will purposely be carried out away from known areas of occurrence of Cuvier's beaked whales.

#### **Bottlenose whale (*Hyperoodon ampullatus*)**

The northern bottlenose whale tends to be sighted in deep temperate or polar waters. In the North Atlantic they are distributed from Nova Scotia to about 70°N in the Davis Strait, along the east coast of Greenland to 77°N and from England to the west coast of Spitzbergen (Waring *et al.* 2000). A resident population in a submarine canyon called "The Gully" offshore of Sable Island has been studied for more than a decade by Hal Whitehead and his group at Dalhousie University. Bottlenose whales also have been sighted in continental slope waters off the east coast of the United States. In the eastern North Atlantic, bottlenose whales are most frequently sighted or stranded in the winter along the Atlantic coasts of western Europe. In the summer, they appear to tend to move to the Norwegian and Greenland Seas, but they are also included in the checklist of cetacean species prepared for the Azores by Reiner *et al.* (1993). Bottlenose whales in the eastern North Atlantic were intensively hunted from the 1880s to the 1920s and then again from 1945-1960s. Although the status of stock in U.S. waters is unknown, a

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depletion in Canadian waters in the 1970's may have impacted the U.S. distribution. Bottlenose whales may be tagged for Project 1 in the North Atlantic.

### **Pilot whales (*Globicephala* spp.)**

Long-finned pilot whales (*Globicephala melas*) and short-finned pilot whales (*Globicephala macrorhynchus*) are difficult to identify to the species level at sea. Due to this identification difficulty, stock status for the individual species is problematic in the North Atlantic, and many references to stock assessment refer to them as *Globicephala* sp. The International Whaling Commission estimates the number of pilot whales in the Central and Eastern North Atlantic at 780,000 (95% confidence intervals 440,000-1,370,000). Long-finned pilot whales tend to have a more northerly distribution than short-finned pilot whales in U.S. waters with some overlap, but both tend to occur along the shelf edge and Gulf Stream (Payne and Heinemann 1993). Short-finned pilot whales are also found on the continental shelf and slope of the northern Gulf of Mexico (Mullin *et al.* 1991). Davis *et al.* (2000) estimate an abundance of 1,471 for short-finned pilot whales in the northern Gulf of Mexico. Short-finned pilot whales are listed as having a moderate sighting rate in the Bahamas Islands (AUTC 2000). Long-finned pilot whales are sighted in the northwestern Mediterranean, but are not common there (Gannier 1998). While pilot whales are not listed under the ESA, in the western North Atlantic they are considered a strategic stock under the MMPA because the estimated average annual fishery-related mortality of pilot whales exceeds the calculated PBR (Waring *et al.* 1999). The primary threat to these animals continues to be fishery by-catch (Fairfield *et al.* 1993; Johnson *et al.* In review). Pilot whales in the Mediterranean have been reported to react to military sonars (Rendell and Gordon 1999). Dr. Tyack proposes to tag pilot whales in the Mediterranean and North Atlantic as part of Project 1 for the purpose of learning more about their diving and acoustic behavior. Relatively little is known about the lives of these animals in the wild, although studies of stomach contents (Gannon *et al.* 1997) and correlative studies of acoustics and behavior (Weilgart and Whitehead 1990) suggest a unique ecology. If Dr. Tyack encounters and is able to tag pilot whales in the Mediterranean as part of Project 2, they would test the ability of the whale-finder sonar to detect them and monitor for responses of the sort noted by Rendell and Gordon (1999). While pilot

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whales in the Gulf of Mexico are not the subject of playback experiments, it is possible that they may be inadvertently exposed to some airgun playbacks directed at sperm whales during Project 3.

### **Dwarf and Pygmy Sperm whales (*Kogia* spp)**

Due to the difficulty of accurately differentiating between dwarf (*Kogia simus*) and pygmy (*K. breviceps*) sperm whales at sea, the population estimates are combined for the two species in the North Atlantic. Little is known about the population structure of these species in the North Atlantic. The best population estimates are for the western North Atlantic region. The combined population estimates for the two species are 420 animals in the western North Atlantic (Waring *et al.* 1999). NOAA Fisheries (2000) lists a northern Gulf of Mexico stock for the dwarf sperm whale. Average abundance for *Kogia* spp. was cited as 547 (CV=0.28). Davis *et al.* (2000) estimate the abundance for *Kogia* spp in the northern Gulf of Mexico as 733. Due to the inability to differentiate species at sea, the population trends are unknown, the minimum population estimates for each of the two species are not available, and consequently PBR cannot be calculated for either species. Fortunately the annual human-related mortality is extremely low for both species in both regions. Estimated annual human induced mortality for dwarf sperm whales in the western North Atlantic is 0.2 animals, unknown for pygmy sperm whales in the same area, and 0 for both species in the Gulf of Mexico. Due to these low human induced mortality rates, none of these four populations of *Kogia* spp. are listed as strategic. Little is known about the distribution, abundance, or human impacts on *Kogia* spp. in the Mediterranean. One dwarf sperm whale is reported to have stranded along the Tuscan coast. AUTECH (2000) reports a moderate sighting rate for pygmy sperm whales in the Bahamas Islands. *Kogia* spp. are reported for the Canary Islands (Carillo N.D.), and there is one report of their stranding along with beaked whales (Simmonds and Lopez-Jurado 1991) in association with naval maneuvers. Relatively little is known about the behavior of these species, and tagging would provide both acoustic and behavioral data to augment what little is known about them. *Kogia* spp. may be tagged opportunistically as part of Project 1. Although they will not be selected as playback subjects, they may be inadvertently exposed to playback of the whale-finder sonar as part of

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Project 2 in the Mediterranean, or to airgun sounds as part of Project 3 in the Gulf of Mexico.

Any exposure of *Kogia* spp. to playbacks would likely involve only a small number of animals and a tiny percentage of even local populations.

**Risso's dolphin (*Grampus griseus*)**

This species is regularly sighted in the North Atlantic, including both the Mediterranean and Gulf of Mexico regions (Gannier 1998, Reiner *et al.* 1993). The best estimate of abundance of Risso's dolphin is for the western north Atlantic region, and is 29,110 (CV=0.29) (Waring *et al.* 2001). Davis *et al.* (2000) estimate the abundance of Risso's dolphins in the oceanic northern Gulf of Mexico at 3,040. Relatively little is known about the behavior of this species, and tagging would provide both acoustic and behavioral data to augment what little is known about the distribution of Risso's dolphins. Waring *et al.* (1999) review data on fisheries mortality in the western North Atlantic. The total fishery mortality for this stock is not > 10% of the calculated PBR for this species. Because the mortality does not exceed PBR, this is not considered a strategic stock under the MMPA. Risso's dolphins will be tagged opportunistically in the Mediterranean and North Atlantic as part of Project 1. Risso's dolphins may be selected as subjects for tests of the whale-finder sonar in the Mediterranean as part of Project 2, and may be unintentionally exposed to playback of airgun sounds in the Gulf of Mexico as part of Project 3. Any exposure of Risso's dolphins to playback would likely involve only a small number of animals.

**Killer whale (*Orcinus orca*)**

Little is known about the population size of killer whales in the North Atlantic. The 1998 and 1999 NOAA U.S. Atlantic marine mammal stock assessment reports indicate that the population size for killer whales in the U.S. Atlantic coastal waters is unknown. AUTEK (2000) estimates a very low sighting rate for killer whales in the Bahamas Islands, but they have been sighted there. Killer whales are sighted in the Canary Islands in the eastern North Atlantic (Carillo N.D.). Notarbartolo di Sciara and Demma (1997) list killer whales as occasionally sighted in the Mediterranean. The Gulf of Mexico stock has a minimum population estimate of 197 (Waring *et*

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*al.* 1995). Davis *et al.* (2000) estimate an abundance of 277 killer whales in the northern Gulf of Mexico. Killer whales may be tagged in the Mediterranean and North Atlantic as part of Project 1, may be tagged and subjects for tests of the whale-finder sonar in the Mediterranean as part of Project 2, and may be unintentionally exposed to playback of airgun sounds in the Gulf of Mexico as part of Project 3. Because of their low abundance in the action areas, any exposure of killer whales to playback would likely involve only a small number of animals and a tiny percentage of even local populations.

#### **False killer whale (*Pseudorca crassidens*)**

The false killer whale has a global distribution in warm temperate and tropical waters. False killer whales are not known to occur in dense concentrations and the population structure is not well known. AUTECH (2000) reports a very low sighting rate of false killer whales in waters near the Bahamas Islands. False killer whales are sighted in the Canary Islands (Carillo N.D.) and Notarbartolo di Sciara and Demma (1997) list false killer whales as occasionally sighted in the Mediterranean. False killer whales are also sighted in the Gulf of Mexico, and Davis *et al.* (2000) estimate an abundance of 817 in the northern Gulf of Mexico. False killer whales may be tagged in the Mediterranean and North Atlantic as part of Project 1, may be tagged and subjects for tests of the whale-finder sonar in the Mediterranean during Project 2, and may be unintentionally exposed to playback of airgun sounds in the Gulf of Mexico as part of Project 3. Due to their low concentrations in the research areas, any exposure of false killer whales to playback would likely involve only a small number of animals and a tiny percentage of even local populations.

#### **Pygmy killer whale (*Feresa attenuata*)**

The pygmy killer whale is widely distributed in tropical and subtropical waters, but not abundant in any location (Leatherwood and Reeves, 1983). Pygmy killer whales are poorly known in most parts of their range, but are usually found in deep water. In the western North Atlantic, they occur from the Carolinas to Texas and the West Indies, and are thought to occur year-round in the Gulf of Mexico (Wursig *et al.*, 2000). Most knowledge of this species is from stranded or

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live-capture specimens. Small numbers have been taken directly and incidentally in both the western and eastern Pacific (Forney *et al.*, 2000). Based on single sighting during a 1992 winter vessel-based survey of the U.S. Atlantic EEZ from Miami, FL to Cape Hatteras, NC, the minimum population estimate for the western North Atlantic stock of pygmy killer whales is six animals (Waring *et al.*, 2001). The level of past or current, direct, human caused mortality of pygmy killer whales in the U.S. Atlantic EEZ is unknown, but there has been historical take of this species in small cetacean fisheries in the Caribbean. There is likely little if any fisheries interaction with pygmy killer whales in the U.S. Atlantic EEZ. There have been no mortalities or serious injuries documented for this species in association with any fisheries within the U.S. Atlantic EEZ (Waring *et al.*, 2001). Pygmy killer whales are not known to occur in the Mediterranean, and thus are not the subject of tagging or whale-finding sonar for Project 2. Pygmy killer whales may be tagged as part of Project 1 and due to their occurrence in the Gulf of Mexico, may be unintentionally exposed to airgun playbacks during Project 3. █

#### **Melon-headed whale (*Peponocephala electra*)**

Melon-headed whales are widely distributed in pelagic tropical waters and are relatively common in the Gulf of Mexico. Davis *et al.* (2000) estimate a population of 3,965 for the oceanic northern Gulf of Mexico. The status of the stock is unknown and there are not enough data to establish a trend in population size. Melon-headed whales are also sighted in Bahamian waters (AUTECH 2000) and are likely to occur in tropical waters of the North Atlantic, but little is known about the distribution and abundance. Melon-headed whales may be tagged in the North Atlantic as part of Project 1, but are not found in the Mediterranean, and so will not be exposed to playbacks during Project 2. Melon-headed whales may be unintentionally exposed to playback of airgun sounds in the Gulf of Mexico as part of Project 3.

#### **Pelagic dolphins:**

**Bottlenose dolphin (*Tursiops truncatus*)**

**Common Dolphin (*Delphinus delphis*)**

**Atlantic spotted dolphin (*Stenella frontalis*)**

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**Pantropical spotted dolphin (*Stenella attenuata*)**

**Spinner dolphin (*Stenella longirostris*)**

**Clymene dolphin (*Stenella clymene*)**

**Striped dolphin (*Stenella coeruleoalba*)**

**Spinner dolphin (*Stenella longirostris*)**

**Rough-toothed dolphin (*Steno bredanensis*)**

**Fraser's dolphin (*Lagenodelphis hosei*)**

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The following information on stock sizes from the western North Atlantic comes from (Waring *et al.* 1999). Species data from the Gulf of Mexico from comes Waring *et al.* (1997):

Species	Population estimate (minimum)	Productivity rates	PBR	Annual human-caused mortality/serious injury	Stock status
<i>Tursiops truncatus</i> (offshore)	13,453 (8,794) <sup>1</sup> 20642 <sup>2</sup>	0.04*	88 <sup>1</sup> 206 <sup>2</sup>	10 <sup>1</sup> 5.3 <sup>2</sup>	Non-strategic
<i>Delphinus delphis</i>	22,215 (16,060) <sup>1</sup> 11,142 <sup>2</sup>	0.04*	154 <sup>1</sup> 107 <sup>2</sup>	780 <sup>1</sup> 612 <sup>2</sup>	Strategic
<i>Stenella frontalis</i>	4,772 (1,617) <sub>1</sub> 23,699	0.04*	16 <sup>1</sup> 236 <sup>2</sup>	9.9 <sup>1</sup> 7.8 <sup>2</sup>	Non-strategic
<i>Stenella attenuata</i>	8450 <sup>2</sup>	0.04	84 <sup>2</sup>	7.8 <sup>2</sup>	Non-strategic
<i>Stenella longirostris</i>	11,251 <sup>3</sup>				Non-strategic
<i>Stenella clymene</i>	10,093 <sup>3</sup>				Non-strategic
<i>Stenella coeruleoalba</i>	31,669 (18,220) <sup>1</sup> 44,500 <sup>2</sup>	0.04*	182 <sup>1</sup> 445 <sup>2</sup>	10.7 <sup>1</sup> 7.3 <sup>3</sup>	Non-strategic
<i>Steno bredanensis</i>	852 (660) <sup>3</sup>	0.04*	6.6	0	Non-strategic
<i>Lagenodelphis hosei</i>	127 <sup>3</sup>				Non-strategic

Table 1. Stock population estimates and status for the Western North Atlantic and/or Gulf of Mexico. <sup>1</sup> Information from (Waring *et al.* 1999). <sup>2</sup> Information from (NOAA NMFS 2000). <sup>3</sup> Information about these species is for the northern Gulf of Mexico as reported in Waring *et al.* (1997). \* The reproductive rates for these species are unknown, so a 4% figure is used for calculations of PBR and stock assessment maximum theoretical reproductive rate based on the constraints of reproductive life history (Barlow *et al.* 1995).

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Little is known about the precise stock structure of dolphins in the Mediterranean and North Atlantic. Dr. Tyack proposes to work opportunistically with the most common species with large population sizes. Gannier (1998) indicates that the striped dolphin (*Stenella coeruleoalba*) is by far the most common cetacean in the northwestern Mediterranean, accounting for 64% of sightings.

Most of the study animals in the proposed research are large cetaceans thought to be sensitive to low frequency noise. However, there is some evidence that pelagic dolphins may be sensitive to higher frequency components of pervasive manmade broadband noises such as air guns (Goold and Fish 1998). Dolphins may also be able to hear some commonly used higher frequency noise sources, such as the ubiquitous sonars used for depth sounding and fish finding. This suggests the potential importance of controlled studies of the impact of noise on pelagic delphinids.

Given the relatively large population sizes in these species (Waring *et al.* 1999), the lack of information about their ecology, and the very low impact of the non-invasive tag, as part of Project 1 Dr. Tyack proposes to attach tags on an opportunistic basis to pelagic delphinids in the North Atlantic and Mediterranean such as striped dolphins, bottlenose dolphins, or common dolphins to learn more about their diving and acoustic behavior. Dr. Tyack also plans to tag delphinids in the Mediterranean as part of Project 2 in order to study the effectiveness of the whale-finding sonars designed to detect marine mammals. The most likely species for this would be bottlenose or striped dolphins. The following species are reported by Davis *et al.* (2000) as sighted in the Gulf of Mexico: *T. truncatus*, *Stenella attenuata*, *Stenella clymene*, *Stenella frontalis*, *Stenella coeruleoalba*, *Stenella longirostris*, *Steno bredanensis*, and *Lagenodelphis hosei*. Since these species are present in the Gulf of Mexico study site, they could be inadvertently exposed to playbacks directed at sperm whales in Project 3.

### **Pinnipeds**

None of the proposed research is focused on any pinniped species. No pinnipeds will be tagged

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as part of any of the projects. In regards to the whale-finding sonar experiments in Project 2, the only pinniped in the Mediterranean is the Mediterranean monk seal, whose distribution is discussed in Section 3.4.1. There are no species of pinnipeds that occur in the Gulf of Mexico and therefore none are expected to be exposed to the air gun playbacks during Project 3.

### **Fish, Seabirds and Invertebrates:**

A description of the abundance of fish, sea birds and invertebrate species is not provided in light of the fact that the sound sources will not have any effect on those species as described in Chapter 4 below; nor should any such species be affected by tagging operations.

#### **3.2.1 Endangered Species**

Many of the large whales that Dr. Tyack proposes to tag and to expose to whale-finding sonar and/or air gun sounds are listed as endangered and are protected under both the MMPA and the ESA.

#### **Humpback whale (*Megaptera novaeangliae*)**

The humpback whale is protected under both the ESA and the MMPA. It is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Reeves, 1998). Humpback whales have a global distribution. The population under consideration in this research involves the North Atlantic, including the rare humpback that might be sighted in the Gulf of Mexico. Humpback whales in the North Atlantic have at least six feeding grounds: Gulf of Maine, Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway. Whales segregating to these different feeding grounds show some genetic differentiation, indicating that they may represent sub-populations (Palsbøll *et al.* 1995; Larsen *et al.* 1996). Whales from all six feeding areas may mix in the West Indies breeding grounds, although some N. Atlantic humpbacks winter in the Cape Verde Islands (Reiner *et al.* 1996). Recent genetic analyses and strong site fidelity have spurred the reclassification of the Gulf of Maine humpbacks as a separate stock (Waring *et al.* 2001). Notarbartolo di Sciara and Demma (1997) do list several strandings of humpback whales in the

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Mediterranean, but this species is so rare there that it is considered extralimital (*i.e.*, not part of their normal geographic distribution) and it is exceedingly unlikely that one might be inadvertently exposed to playback there.

The best estimate of humpback numbers in the North Atlantic is 10,600 (95% CI 9,300 -12,100) (Waring *et al.*, 1999). This number is based on survey data from the 1992 Year of the North Atlantic Humpback project that was a large-scale study of humpback whales throughout the North Atlantic. Photographic mark-recapture analyses from these cruises gave an ocean-basin estimate of the north Atlantic population as 10,600 (Smith *et al.*, 1999). The population(s) of humpback whales in the North Atlantic appears to be increasing (Barlow and Clapham, 1997). Human impact may be slowing the increase of humpback whales in the western North Atlantic by interactions with fisheries and vessel collisions. Of the carcasses that were suitable for evaluation over seven years, 60% showed evidence of anthropogenic causes of death (30% from ship strikes, 25% with gear entanglement and 5% with evidence of both factors) (Wiley *et al.* 1995). The mean annual mortality from fisheries is 3.9, while the mean annual mortality from vessel strikes is 1.5 (Waring *et al.* 1999). For the Gulf of Maine stock, the best estimate of population size is 816 (Waring *et al.* 2001). Less is known about the size and potential human impacts on humpback whales in the Eastern North Atlantic. AUTECH (2000) and Carillo (N.D.) list humpback whales in their checklist of cetaceans sighted in Bahamian and Canarian waters, respectively, but the sighting probability is listed as low. Humpback whales have been sighted in the Gulf of Mexico (Jefferson and Shiro, 1997), but were not sighted often enough for calculation of abundance by Davis *et al.* (2000). Würsig *et al.* (2000) report a 1997 sighting of a group of six humpbacks about 250 km east of the Mississippi Delta at a depth of 1000 m. They also report two strandings for the Gulf and note that humpback songs have been recorded in the northwestern part of the Gulf of Mexico. Humpback whales may be selected for tagging as part of Project 1 in the North Atlantic and there is a very small chance that they may be inadvertently exposed to sound playbacks as part of Project 3 in the Gulf of Mexico. Since humpback whales are viewed as extralimital in the Mediterranean, Dr. Tyack does not expect any potential for playback takes in Project 2.

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### **Sei Whale (*Balaenoptera borealis*)**

All populations of sei whales seem to overwinter in warm temperate or sub-tropical waters, and have a pole-ward summer feeding migration. There is no evidence of any resident populations of sei whales. Sei whales did not receive international protection until 1970, when catch quotas for the North Pacific became species based. Complete protection was given in the North Pacific in 1976. Quotas were put into effect in the North Atlantic in 1977. All legal whaling for sei whales stopped when the moratorium on commercial whaling took effect in the Northern Hemisphere in 1986. Sei whales are protected both by the Endangered Species Act and the Marine Mammal Protection Act. They are listed in CITES Appendix I (Reeves *et al.*, 1998).

Donovan (1991) concludes that the stock identity of sei whales in the North Atlantic is an unresolved research question, but the International Whaling Commission did set catch limits for two stocks in Nova Scotia and Iceland-Denmark Strait. For management purposes, NOAA Fisheries recognizes a Nova Scotia stock of sei whales that extends from the continental shelf of the NE US to Newfoundland (Waring *et al.* 1999). This Nova Scotia stock of sei whales was estimated at 1,400-2,200 in the late sixties (Horwood, 1987), though little apparent effort has been made to assess this stock in the past 10 years. The current number of sei whales in the Nova Scotia stock is unknown. Because so little information is available about the stock, it is not possible to assess the current status of this stock. Less is known about the stock structure, population size and potential human impacts on sei whales in the Eastern North Atlantic. There have been no reported fisheries related mortality or serious injury to sei whales observed by NOAA Fisheries from 1991-1997. There was one report in 1994 of a ship strike mortality from a sei whale carcass found on the bow of a container ship when it docked in Boston (Waring *et al.*, 1999).

Sei whales are reported in the Carillo (N.D.) checklist for cetaceans in the Canary Islands, and they may be sighted along the eastern coast of the US. Sei whales are not reported for the Mediterranean (Notarbartolo di Sciara and Demma 1997). Sei whales have been sighted in the Gulf of Mexico (Jefferson and Shiro, 1997), but were not sighted enough for calculation of abundance by Davis *et al.* (2000). Sei whales may be selected for tagging as part of the Project 1

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research. It is extremely improbable that they would be inadvertently exposed to playbacks in the Mediterranean, but they are included for Project 3 in the unlikely case of exposure in the Gulf of Mexico.

### **Fin Whale (*Balaenoptera physalus*)**

The fin whale is protected under both the ESA and the MMPA and is listed in Appendix I of the CITES (Reeves *et al.*, 1998). Stocks of fin whales around the world were severely depleted by the whaling industry in the 18<sup>th</sup>-20<sup>th</sup> centuries. Under the 1946 International Convention for the Regulation of Whaling, a minimum size limit of 55 ft was put in effect in the North Pacific. The International Whaling Commission (IWC) did not begin to manage commercial whaling for fin whales until 1969 in the North Pacific (Allen, 1980) and 1976 in the North Atlantic (Sigurjonsson 1988). The fin whale was given full protection from Antarctic whaling in the 1976/1977 season, the North Pacific in the 1976 season, and the North Atlantic in the 1987 season.

The fin whale populations in the North Atlantic have been separated into several different stocks for management purposes: the Western North Atlantic (Waring *et al.*, 1997), the British Isles-Spain-Portugal stock areas (Buckland *et al.*, 1992a), and the East Greenland/Iceland Fin Whale population (Buckland *et al.*, 1992b). The IWC more finely divides North Atlantic fin whales into seven stock areas: Nova Scotia, Newfoundland-Labrador, West Greenland, East Greenland-Iceland, British Isles-Spain-Portugal, West Norway-Faroe Islands, and North Norway (Donovan 1991). The fin whale population size for the Western North Atlantic has been estimated to be about 5000 (Hain *et al.* 1992) from a 1978-1982 survey (Reeves *et al.*, 1998). The current best estimate is 2,814 and the minimum population estimate is 2,362 (Waring *et al.*, 2001). The East Greenland/Iceland Fin Whale population size has been estimated at 10,000 (95 % CI 7,600-14,200) individuals from 1987 and 1989 summer shipboard surveys (Buckland *et al.*, 1992b). The number of Eastern Atlantic fin whales is estimated to be 17,000 (95% CI 10,400-28,900) for the British isles-Spain-Portugal stock areas (Buckland *et al.*, 1992a). Fin whales have not been reported for the Bahamas (AUTEC 2000). Fin whales have been sighted in the Gulf of Mexico

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(Jefferson and Shiro, 1997), but were not sighted often enough for calculation of abundance by Davis *et al.* (2000).

The Mediterranean fin whale population size based on a sighting survey in the summer of 1991 in the Western Mediterranean is estimated at 3,583 (SE: 967 95% CI: 2,130-6,027) (Forcada, 1996). The fin whale is the most common large cetacean in the Mediterranean. It is frequently reported in the Western Mediterranean (Gannier 1998). During the summer months, the whales seem to congregate in the highly productive waters of the north-western basin. While fin whales are sighted in the eastern North Atlantic near the approaches to the Mediterranean (*e.g.* Canary Islands, Carillo N.D.), there is little evidence that the population of the Western Mediterranean migrates out to the Atlantic through the strait of Gibraltar; genetic differentiation of Mediterranean fin whales suggests that they may form at least a subpopulation (Bérubé *et al.*, 1998).

The human factors affecting the growth of this population are best documented for the western North Atlantic and include mortality associated with fishing gear and vessel collision. Three records of stranded, floating, and injured fin whales from 1995-1997 showed evidence of fishery interactions (Waring *et al.*, 2001). The minimum annual rate of serious injury and mortality from fishery interactions is 0.6 fin whales. Between 1995-1999 there was sufficient information to suggest that six fin whales were killed in vessel collisions (Waring *et al.*, 200).

Fin whales may be selected for tagging in Project 1, and may be selected as subjects for playbacks in Project 2. There is a slight chance that a rare finback in the Gulf of Mexico might incidentally be exposed to sound playbacks as part of Project 3.

### **Blue whale (*Balaenoptera musculus*)**

The blue whale is protected under both the ESA and the MMPA and is listed in Appendix I of the CITES (Reeves 1998). In the past, blue whales were extensively hunted worldwide; in the North Atlantic, their numbers were so depleted that they remain rare in formerly important

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habitats in the northern and northeastern Atlantic (Sigurjónsson and Gunnlaugsson 1990). Little is known about the population size for blue whales anywhere in the North Atlantic other than in the Gulf of St. Lawrence, where Sears *et al.* (1987) have identified over 300 individuals. By comparison, the IWC estimates 460 blue whales for the entire southern oceans (95% confidence limits 210-1000). The NOAA Fisheries uses the Sears *et al.* (1987) data for estimating minimum population size in the western North Atlantic. Davis *et al.* (2000) list blue whales in their checklist for the Gulf of Mexico, as two animals have been reported stranded, one in Texas and one in Louisiana (Würsig *et al.*, 2000), but their own surveys did not sight any. Clark (1995) has acoustically detected calls of blue whales in the North Atlantic, especially near the Grand Banks of Newfoundland and west of the United Kingdom. Blue whales are listed in a checklist of cetaceans in the Canary Islands (Carillo N.D.). Sigurjónsson and Gunnlaugsson (1990) estimate that the blue whales sighted near Iceland appear to be increasing at a rate of 4.9% per year, and Waring *et al.* (1999) assume a maximum net productivity rate of 4%. Blue whales may be selected for tagging as part of Project 1. It is unlikely that they would be inadvertently exposed to playbacks in the Mediterranean (Project 2), where they are extralimital. They are rare in the Gulf of Mexico, but to be conservative two takes via incidental exposure to playback are included for Project 3.

### **Sperm whale (*Physeter macrocephalus*)**

The sperm whale is protected under both the ESA and the MMPA and is listed in Appendix I of the CITES (Reeves *et al.*, 1998). Sperm whales are found throughout the world's oceans in deep waters between 60°N and 60°S. Sperm whales are highly mobile – one sperm whale wounded in the Azores was taken off Denmark the next year (Reeves and Whitehead 1997), and another Azorean sperm whale was taken by Icelandic whalers (Martin 1982). Reeves and Whitehead (1997) suggest that while sperm whales show a clear pattern of geographical segregation of different social groupings, they may not have a well-defined sub population structure in ocean basins. The IWC (Donovan 1991) and the U.S. NOAA Fisheries (Waring *et al.*, 1999) recognize the entire North Atlantic as one stock area. The North Atlantic stock of sperm whales is estimated to be at least 1,617 animals with a best estimate of 2,698 animals according to the

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latest NOAA Fisheries/NEFSC stock assessment (Waring *et al.*, 1999), but this estimate just includes whales sighted off the eastern coast of the United States. Davis *et al.* (2000) estimate a population of about 530 sperm whales in the oceanic northern Gulf of Mexico, where they tend to be sighted in waters of about 1000 m depth and are concentrated south of the Mississippi River delta.

In the Mediterranean sperm whales are widely distributed from the Alboran Sea to the Levant Basin, mostly over steep slope and deep offshore waters. Sperm whales are rarely sighted in the Sicilian Channel, and are vagrant in the northern Adriatic and Aegean Seas (Notarbartolo di Sciara and Demma, 1997). In the Italian seas, sperm whales are found more frequently over the continental slope off western Liguria, western Sardinia, northern and eastern Sicily, and both coasts of Calabria. Though once thought to be numerous in Italian waters, when relative abundance data became available in the mid 1990s (Notarbartolo di Sciara *et al.*, 1993; Marini *et al.*, 1996), sighting frequencies of sperm whales were surprisingly low compared to other regular species, perhaps indicating habitat degradation or extensive human induced mortality for sperm whales in Italian waters. Possible causes of this condition include the large number of accidental captures in high seas swordfish driftnets (Notarbartolo di Sciara, 1990), considered to be having a potential impact on the population (International Whaling Commission, 1994), and disturbance from intense marine traffic, including high-speed passenger vessels (hydrofoils). Environmental noise deriving from mineral prospecting (airgun) and military operation is another source of concern (Notarbartolo di Sciara and Gordon, 1997). Little information is available either on Mediterranean sperm whale population size or on the population relationship between sperm whales in the Mediterranean and the North Atlantic. However, initial genetic information (Engelhaupt, pers. comm.), the frequent observation of neonates in the Mediterranean, and the scarcity of sightings from the Gibraltar area (Bayed and Beaubrun, 1987) point to the possibility that sperm whales in the Mediterranean, like fin whales, may form a resident, reproductively isolated population. Sperm whales are sighted in the North Atlantic just outside of the Mediterranean, for example in the Canary Islands (Carillo N.D.).

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Sperm whales were hunted as late as the 1970s in the North Atlantic, but they live far enough from shore that they are seldom impacted by human fisheries and are not known to be at great risk of vessel collision. There are conflicting reports on whether sperm whales respond strongly to low to moderate exposures to manmade noise. Watkins *et al.* (1985) reported that sperm whales in the Windward Islands exposed to military sonars during the Grenada invasion, silenced, altered their activity patterns, and moved away. Watkins and Schevill (1975) report that sperm whales cease clicking when they hear sounds of pingers emitting one short pulse/sec when the source level is in the 110-130 dB re 1  $\mu$ Pa range. Sperm whales are also reported to react to sounds of seismic exploration at great ranges. Mate *et al.* (1994) report that sperm whales move as far as 50 km away after the onset of seismic surveys in the Gulf of Mexico. Bowles *et al.* (1994) report that sperm whales in the southern Indian Ocean sometimes ceased vocalizing when pulses from an airgun area 300+ km away were heard. In contrast, Madsen *et al.* (2002) report no cessation of vocalization for sperm whales exposed to seismic sounds up to 146 dB re 1  $\mu$ Pa pk-pk. Observers on or near seismic vessels also found little evidence of avoidance or disruption for sperm whales in the presence of seismic survey (Stone 1997, 1998, 2000, 2001).

Sperm whales may be tagged for baseline observations in Project 1 in the Mediterranean and the North Atlantic. Additionally, sperm whales will be tagged for testing a whale-finding sonar in the Mediterranean as part of Project 2. Sperm whales will also be tagged and the subject of controlled exposure experiments to seismic sounds from an airgun array in the Gulf of Mexico as part of Project 3.

### **Mediterranean monk seal (*Monachus monachus*)**

The Mediterranean monk seal is endangered and the species has been extirpated from much of its historical range. There is no longer a stable population of monk seals present in Italian waters. The species was historically present in the Ligurian coast and in particular in the Levanto area and in some Provençal areas of France until the middle of the 1900's, but is now absent from these coasts. The species was present until the early 1980s in some areas of Corsica. The last

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sighting in Corsica occurred in 1991 in the area of Calvi. It used to be present in the Tuscan archipelago and particularly in the island of Monte cristo but appears to have disappeared also in the early 1980s. The last sighting in the Tuscan archipelago was in 1986. Monk seal sightings have occurred during the last 10 years in northeastern Sardinia (Maddalena archipelago) and southwestern Sardinia (Carloforte area). Other sightings occur in the Pelagic islands of Sicily. These are probably animals moving in and out from Tunisian-Algerian waters and possibly spending part of their time in nearby Italian waters (southwestern Sardinia and in some of the Pelagic islands such as Pantelleria). While it is true that adult female and male individuals are capable of dispersing up to 160 miles over several months, it is highly unlikely, given the scanty distribution present in the north African coast, that individuals may be observed moving as far north as the Ligurian sea.

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Based on the current distribution of Mediterranean monk seals there is an extremely low probability that a seal will be exposed to the whale-finding sonar during Project 2.

**West Indian manatee (*Trichechus manatus*)**

The West Indian manatee occurs in rivers, estuaries, lagoons, and coastal waters from the southeastern U.S. to Brazil. There are two subspecies of the West Indian manatee: the Florida manatee (*T. m. manatus*) and the Antillean manatee (*T. m. latirostris*). Manatees are protected under the MMPA. The Florida manatee stock is listed as endangered under the ESA and is also a CITES Appendix I species. Manatees are herbivorous, feeding mainly on submerged vegetation and thus are commonly found near in shallow grass beds in coastal and riverine habitats. Manatee distribution in U.S. waters is primarily related to season and water temperature (USFWS 2001) as well as the availability of vegetation. During the colder months, when water temperatures are below 20°C, manatees primarily limited to aggregate within the confines of natural and artificial warm-water refuges or move towards the southern tip of Florida. As water temperatures rise, manatees disperse from winter aggregation areas. During the summer, sightings drop off rapidly north of Georgia and are rare north of Cape Hatteras (USFWS 2001). In the Gulf of Mexico, summer sightings of the Florida manatee are increasingly rare west of the Suwanee River in Florida (USFWS 2001). However, manatees

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have been observed off of Texas, Louisiana and Mississippi virtually every summer since 1970 (Wursig *et al.*, 2000).

Manatees are not the focus of any of the proposed research. Manatees will not be tagged under any of the Projects (1-3) and do not occur in the Mediterranean Sea where Project 2 activities will be performed. Because manatees occur mainly in shallow nearshore or fresh waters, and their range is mostly restricted to Florida waters in the Gulf of Mexico, and the airgun playbacks of Project 3 are focusing on deep waters, especially where sperm whales are known to concentrate (typically south of the Mississippi River delta), manatees are not likely to be exposed to any acoustic sounds associated with the proposed research.

## **Sea Turtles**

### **Loggerhead turtle (*Caretta caretta*)**

The loggerhead sea turtle is listed as threatened under the ESA. No critical habitat has been designated for this species. Loggerheads occur throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans and inhabit continental shelves and estuarine environments.

Loggerheads are the most abundant species of sea turtle occurring in U.S. waters. In the western Atlantic, loggerheads nest from Louisiana to Virginia. Five genetically distinct nesting subpopulations have been identified in the western North Atlantic and southeastern U.S.: (1) northern nesting subpopulation, occurring from North Carolina to northeast Florida at about 29° N (approximately 7,500 nests in 1998); (2) south Florida nesting subpopulation, occurring from 29° N on the east coast to Sarasota on the west coast (approximately 83,400 nests in 1998); (3) Florida panhandle nesting subpopulation, occurring at Eglin Air Force Base and the beaches near Panama City, Florida (approximately 1,200 nests in 1998); (4) Yucatán nesting subpopulation, occurring on the eastern Yucatán Peninsula, Mexico (Márquez 1990) (approximately 1,000 nests in 1998) (TEWG 2000, Table 11); and (5) Dry Tortugas nesting subpopulation, occurring in the islands of the Dry Tortugas, near Key West, Florida (approximately 200 nests per year) (NMFS

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SEFSC 2001). Between 1989 and 1998, the total number of nests laid along the U.S. Atlantic and Gulf coasts ranged from 53,014 to 92,182 annually, with a mean of 73,751.

Loggerheads originating from the western Atlantic nesting aggregations are believed to lead a pelagic existence in the North Atlantic Gyre for as long as 7-12 years. Turtles in this life history stage are called “pelagic immatures” and are best known from the eastern Atlantic near the Azores and Madeira and have been reported from the Mediterranean as well as the eastern Caribbean (Bjorndal *et al.* in press). Stranding records indicate that when pelagic immature loggerheads reach 40-60 cm SCL they recruit to coastal inshore and nearshore waters of the continental shelf throughout the U.S. Atlantic and Gulf of Mexico.

Benthic immatures have been found from Cape Cod, Massachusetts, to southern Texas, and occasionally strand on beaches in northeastern Mexico (R. Márquez-M., pers. comm.). Benthic immature loggerheads foraging in northeastern U.S. waters are known to migrate southward in the fall as water temperatures cool (Epperly *et al.*, 1995b; Keinath 1993; Morreale and Standora 1999; Shoop and Kenney 1992), and migrate northward in spring.

Adults have been reported throughout the range of this species in the U.S. and throughout the Caribbean Sea. Non-nesting, adult female loggerheads are reported throughout the U.S. and Caribbean Sea; however, little is known about the distribution of adult males who are seasonally abundant near nesting beaches during the nesting season. Aerial surveys suggest that loggerheads (benthic immatures and adults) in U.S. waters are distributed in the following proportions: 54% in the southeast U.S. Atlantic, 29% in the northeast U.S. Atlantic, 12% in the eastern Gulf of Mexico, and 5% in the western Gulf of Mexico (TEWG 1998).

Loggerhead sea turtles are not the subject of any of the proposed research; however, their distribution in the Mediterranean and Gulf of Mexico suggests that they may be present during playbacks of the whale-finder sonar and the airguns (Projects 2 and 3). The research protocols proposed by Dr. Tyack contain mitigation measures if sea turtles are observed in the study area

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(Section 2.3.2). See Section 4.1.2 for a discussion on the possible effects of the proposed research on sea turtles.

### **Green turtle (*Chelonia mydas*)**

The green sea turtle was listed in 1978, with all populations listed as threatened, except for the breeding populations of Florida and the Pacific coast of Mexico, which are listed as endangered.

Critical habitat for the green sea turtle has been designated for the waters surrounding Isla Culebra, Puerto Rico and its associated keys. Green turtles are distributed circumglobally, mainly in waters between the northern and southern 20° C isotherms (Hirth 1971). The green turtle is limited to extreme southern portions of the Mediterranean basin (where it nests) and is not found in the Ligurian sea.

The complete nesting range of the green turtle within U.S. jurisdiction includes sandy beaches of mainland shores, barrier islands, coral islands, and volcanic islands between Texas and North Carolina and at the U.S. Virgin Islands (U.S.V.I.) and Puerto Rico (NMFS and USFWS 1991a).

After hatching, green sea turtles go through a post-hatchling pelagic stage where they are associated with drift lines of algae and other debris. The majority of a green turtle's life is spent on the foraging grounds. Green turtle foraging areas in the southeast United States include any neritic waters having macroalgae or sea grasses near mainland coastlines, islands, reefs, or shelves, and any open-ocean surface waters, especially where advection from wind and currents concentrates pelagic organisms (Hirth 1997, NMFS and USFWS 1991b). Principal benthic foraging areas in the region include Aransas Bay, Matagorda Bay, Laguna Madre, and the Gulf inlets of Texas (Doughty 1984, Hildebrand 1982, Shaver 1994), the Gulf of Mexico off Florida from Yankeetown to Tarpon Springs (Caldwell and Carr 1957, Carr 1984), Florida Bay and the Florida Keys (Schroeder and Foley 1995), the Indian River Lagoon System, Florida (Ehrhart 1983), and the Atlantic Ocean off Florida from Brevard through Broward counties (Wershoven and Wershoven 1992, Guseman and Ehrhart 1992), and the northwestern coast of the Yucatan Peninsula. Additional important foraging areas in the western Atlantic include the Culebra

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archipelago and other Puerto Rico coastal waters, the south coast of Cuba, the Mosquito coast of Nicaragua, the Caribbean coast of Panama, and scattered areas along Colombia and Brazil (Hirth 1971). Adults of both sexes are presumed to migrate between nesting and foraging habitats along corridors adjacent to coastlines and reefs.

In the western Atlantic, the largest nesting beach at Tortuguero, Costa Rica, has shown a long-term increasing trend since monitoring began in 1971. The estimated number of emergences was under 20,000 in 1971 and over 40,000 in 1996 with a high estimate of over 100,000 emergences in 1995 (Bjorndal *et al.*, 1999). The pattern of green turtle nesting shows biennial peaks in abundance, with a generally positive trend during the ten years of regular monitoring since establishment of the index beaches in 1989, perhaps due to increased protective legislation throughout the Caribbean (Meylan *et al.* 1995). Selected beaches in Florida have been extensively and consistently surveyed since 1989. From 1989 through 1999, the estimated number of females nesting annually ranged from 109 to 1,389 (Meylan *et al.*, 1995 and Florida Marine Research Institute Statewide Nesting Database, unpublished data; estimates assume 4 nests per female per year, Johnson and Ehrhart, 1994). This gives an estimate of total nesting females that ranges from 705 to 1,509 during the period 1990-1999. It is important to note that because methodological limitations make the clutch frequency number (4 nests/female/year) an under-estimate (by as great as 50%), a more conservative range for numbers of green turtles nesting in Florida is 470 to 1,509 nesting females between 1990 and 1999.

Green turtles were once abundant enough in the shallow bays and lagoons of the Gulf to support a commercial fishery, which landed over one million pounds of green turtles in 1890 (Doughty 1984). Doughty reported the decline in the turtle fishery throughout the Gulf of Mexico by 1902. Currently, green turtles are uncommon in offshore waters of the northern Gulf, but abundant in some inshore embayments.

Green sea turtles are not the subject of any of the proposed research; however, their distribution in the Mediterranean and Gulf of Mexico suggests that they may be present during playbacks of

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the whale-finder sonar and the airguns (Projects 2 and 3). See Sections 2.3.2 for the mitigation measures proposed relating to sea turtles and Section 4.1. for a discussion on the possible effects of the proposed research on sea turtles.

### **Kemp's ridley turtle (*Lepidochelys kempii*)**

The Kemp's ridley is listed as endangered under the ESA. No critical habitat has been identified for this species. Of the seven extant species of sea turtles of the world, the Kemp's ridley has declined to the lowest population level. This species has a very restricted range relative to other sea turtle species. It appears that adult Kemp's ridley turtles are restricted somewhat to the Gulf of Mexico in shallow near shore waters, although adult-sized individuals are found on the Eastern Seaboard of the United States.

Most of the entire population of adult females nest in daytime aggregations known as arribadas at a single locality, Rancho Nuevo, a stretch of beach in Mexico (Pritchard 1969). Adult female populations were estimated to be in excess of 40,000 individuals in 1947 (Hildebrand 1963). By the early 1970s, the world population estimate of mature female Kemp's ridleys had been reduced to 2,500-5,000 individuals. The population declined further through the mid-1980s. Recent observations of increased nesting suggest that the decline in the ridley population has stopped and there is cautious optimism that the population is now increasing (TEWG 1998).

Nesting for this species occurs from April into July and is essentially limited to the beaches of the western Gulf of Mexico, primarily in the Mexican state of Tamaulipas. Juvenile/subadult Kemp's ridleys have been found along the Eastern Seaboard of the United States and in the Gulf of Mexico. Atlantic juveniles/subadults travel northward with vernal warming to feed in the productive, coastal waters of Georgia through New England, returning southward with the onset of winter to escape the cold (Lutcavage and Musick 1985, Henwood and Ogren 1987, Ogren 1989). The shallow nearshore waters of the Gulf of Mexico are believed to provide important developmental habitat for juvenile Kemp's ridley turtles. Studies suggest that subadult Kemp's ridleys stay in shallow, warm, nearshore waters in the northern Gulf of Mexico until cooling

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waters force them offshore or south along the Florida coast (Renaud 1995). Little is known of the movements of the post-hatching, planktonic stage within the Gulf.

Kemp's ridley sea turtles are not the subject of any of the proposed research; however, their distribution in the Gulf of Mexico suggests that they may be present during playbacks of the airguns (Projects 3). See Sections 2.3.2 for the mitigation measures proposed relating to sea turtles and Section 4.1. for a discussion on the possible effects of the proposed research on sea turtles

#### **Leatherback turtle (*Dermochelys coriacea*)**

The leatherback is listed as endangered under the ESA. Critical habitat for the leatherback includes the waters adjacent to Sandy Point, St. Croix, U.S.V.I. The leatherback ranges farther than any other sea turtle species, exhibiting broad thermal tolerances (NMFS and USFWS 1995). Leatherbacks are widely distributed throughout the oceans of the world, and are found in the Atlantic, Pacific, Caribbean, and the Gulf of Mexico (Ernst and Barbour 1972). Adult leatherbacks forage in temperate and subpolar regions from 71°N to 47°S latitude in all oceans and undergo extensive migrations between 90°N and 20°S, to and from the tropical nesting beaches. Leatherbacks are predominantly distributed pelagically, however can be found in nearshore waters. In the Atlantic Ocean, leatherbacks have been recorded as far north as Newfoundland, Canada, and Norway, and as far south as Uruguay, Argentina, and South Africa (NMFS SEFSC 2001). Leatherbacks do not nest in the Mediterranean, and not much is known regarding how many individuals enter the Mediterranean through passive navigation and where these individuals go to, nor how long they remain there (where they presumably just feed). Female leatherbacks nest from the southeastern United States to southern Brazil in the western Atlantic and from Mauritania to Angola in the eastern Atlantic. The most significant nesting beaches in the Atlantic, and perhaps in the world, are in French Guiana and Suriname (NMFS SEFSC 2001).

Recent declines have been seen in the number of leatherbacks nesting worldwide (NMFS and

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USFWS 1995). Initial estimates of the worldwide leatherback population were between 29,000 and 40,000 breeding females (Pritchard 1971), later refined to approximately 115,000 adult females globally (Pritchard 1982). An estimate of 34,500 females (26,200 - 42,900) was made by Spotila *et al.* (1996), along with a claim that the species as a whole was declining and local populations were in danger of extinction (NMFS SEFSC 2001). Though the Pacific population is estimated to number only 3,000 total adult and subadult animals (Spotila *et al.*, 2000), the status of the Atlantic population is less clear. In 1996, it was reported to be stable, at best (Spotila *et al.* 1996), but numbers in the Western Atlantic were reported to be on the order of 18,800 nesting females. According to Spotila (pers. comm.), the Western Atlantic population currently numbers about 15,000 nesting females, whereas current estimates for the Caribbean (4,000) and the Eastern Atlantic (*i.e.*, off Africa, numbering ~ 4,700) have remained consistent with numbers reported by Spotila *et al.* in 1996.

The status of the leatherback population in the Atlantic is difficult to assess since major nesting beaches occur over broad areas within tropical waters outside the United States. Although leatherbacks occur in all U.S. Atlantic, Gulf, and Caribbean waters, it is estimated that about 250 females now visit nesting sites in the U.S. (*i.e.*, Florida, Puerto Rico and the U.S. Virgin Islands) (NMFS SEFSC 2001). In summary, in the western Atlantic, the nesting aggregation in French Guiana has been declining at about 15% per year since 1987. From 1979-1986, the number of nests was increasing at about 15% annually. The number of nests in Florida and the U.S. Caribbean has been increasing at about 10.3% and 7.5%, respectively, per year since the early 1980s but the magnitude of nesting is much smaller than that along the French Guiana coast, and as mentioned above the French Guiana nesting complex is the largest in the western North Atlantic Ocean (see NMFS SEFSC 2001).

Leatherback sea turtles are not the subject of any of the proposed research; however, their distribution in the Gulf of Mexico and occasional presence in the Mediterranean suggest that they may be present during playbacks of the whale-finder sonar and the airguns (Projects 2 and 3). See Sections 2.3.2 for the mitigation measures proposed relating to sea turtles and Section

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4.1. for a discussion on the possible effects of the proposed research on sea turtles

**Hawksbill turtle (*Eretmochelys imbricata*)**

The hawksbill turtle is listed as endangered under the ESA. Only five regional nesting populations remain with more than 1,000 females nesting annually (Seychelles, Mexico, Indonesia, and two in Australia) (Meylan and Donnelly 1999). Most populations are declining, depleted, or remnants of larger aggregations. Critical habitat for the hawksbill includes the waters around Mona and Monito Islands, Puerto Rico. The species occurs in all ocean basins although it is relatively rare in the Eastern Atlantic and Eastern Pacific, and absent from the Mediterranean Sea. Hawksbills are the most tropical of the marine turtles, ranging from approximately 30°N to 30°S. They are closely associated with coral reefs and other hard-bottom habitats, but they are also found in other habitats including inlets, bays and coastal lagoons.

The life history of hawksbills consists of a pelagic stage that lasts from hatching until they are approximately 22 - 25 cm in straight carapace length (Meylan 1988, Meylan in prep.), followed by residency in developmental habitats (foraging areas where immatures reside and grow) in coastal waters. Adult foraging habitat, which may or may not overlap with developmental habitat, is typically coral reefs, although other hard-bottom communities and occasionally mangrove-fringed bays may be occupied.

In the Western Atlantic, the largest hawksbill nesting population occurs in the Yucatán Península of Mexico, where several thousand nests are recorded annually in the states of Campeche, Yucatán, and Quintana Roo (Garduño-Andrade *et al.* 1999). Important but significantly smaller nesting aggregations are documented elsewhere in the region in Puerto Rico, the U.S. Virgin Islands, Antigua, Barbados, Costa Rica, Cuba, and Jamaica (Meylan 1999a). Estimates of the annual number of nests for each of these areas are of the order of hundreds to a few thousand. Nesting within the U.S. is restricted to Puerto Rico, the U.S. Virgin Islands, and, rarely, Florida (Eckert 1995, Meylan 1999a, Florida Statewide Nesting Beach Survey database). At the two principal nesting beaches in the U.S. Caribbean where long-term monitoring has been carried

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out, populations appear to be increasing (Mona Island, Puerto Rico) or stable (Buck Island Reef National Monument, St. Croix, USVI) (Meylan 1999a).

It is unlikely that hawksbill sea turtles will be present in either the Mediterranean Sea or the Gulf of Mexico where acoustic experiments are proposed.

## **CHAPTER 4 ENVIRONMENTAL CONSEQUENCES**

### **4.1 Direct Effects**

This chapter represents the scientific and analytic basis for comparison of the direct, indirect, and cumulative effects of the alternatives. Regulations for implementing the provisions of NEPA require consideration of both the context and intensity of a proposed action (40 CFR Parts 1500-1508). Thus, the significance must be analyzed in several contexts, such as society as a whole, the affected resources and regions, and the affected interests. Intensity refers to the severity of the impact and the following 10 specific aspects that must be considered: (1) beneficial and adverse effects; (2) effects on public health and safety; (3) unique characteristics of the geographic area (*e.g.*, proximity to historic or cultural resources, park lands, and ecologically critical areas); (4) degree to which possible effects are likely to be highly controversial; (5) degree to which possible effects are highly uncertain or involve unique or unknown risks; (6) precedent-setting actions; (7) whether the action is related to other actions with individually insignificant but cumulatively significant impacts; (8) loss or destruction of significant scientific, cultural, or historical resources (including adverse effects on sites listed in the National Register of Historic Places); (9) degree to which action may adversely affect an endangered or threatened species or designated critical habitats; and (10) violation of Federal, state, or local laws imposed for protection of the environment.

The economics effects of the Alternatives are minimal and mainly involve the effects on the researchers involved in the research, as well as any industries that support the research, such as charter vessels, and suppliers of equipment needed to accomplish the research. The effects of all

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alternatives considered would likely be equally positive with respect to these entities.

The potential for loss or destruction of cultural or historic resources is also likely equal among the alternatives, and negligible given the nature of the research and permit requirements.

The proposed scientific research is not likely to affect any critical habitat or essential fish habitat because none of the proposed techniques have a measurable potential to alter any substrate or the marine environment in general.

The issue most relevant to the analysis of Alternatives is the potential for negative impacts on wildlife within the action area. Marine species, including mammals, sea birds, sea turtles and fish, are likely affected to varying degrees by vessel traffic in their environment. However, the amount of exposure to impacts related to vessel traffic associated with the scientific research in the alternatives is largely insignificant compared to the existing background levels of exposure. There is the potential for some incidental harassment of other marine mammals that may be in the vicinity during close approaches of targeted species during tagging or focal follow operations, but the number of other marine mammals that may be harassed is small and any harassment is not likely to have a measurable long-term effect on stocks or populations. Similarly, there are not likely to be measurable impacts on sea turtle, sea bird or fish species from close approach activities.

Therefore, the following analysis of effects will focus primarily on the potential impacts of the acoustic controlled exposure experiments on any animals or humans in the vicinity of the sound source.

#### **4.1.1 Effects of Alternative 1 – No Action**

Under the No Action Alternative, the permit would not be issued and the proposed tagging and acoustic experiments would not be performed. Marine animals living within the action area would still be exposed to vessel traffic and anthropogenic sounds that currently occur in those

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environments as part of the Status Quo.

**Research:** As previously mentioned, Dr. Tyack does possess a scientific research permit (No. 981-1578) that would still exist under the No Action Alternative. However, the research authorized in that permit is very limited in scope. No research would occur in U.S. waters; all would be limited to the Mediterranean and Ligurian Seas and the Atlantic waters off the Azores. The effects of tagging and close approach on marine mammals would be the same as those described below in Section 4.1.2. Playbacks of airguns or sperm whale codas are not authorized under the current permit as a result of the litigation, and thus none would occur under the No Action Alternative. Tests of whale-finding sonar could occur under the current permit (see Section 2.1), but these experiments were already conducted and the source levels did not detect echoes of marine mammals. Therefore, the whale-finding sonar research as permitted under the No Action Alternative has limited scientific use. Should Dr. Tyack choose to conduct such research, the effects of the whale-finding sonar would be similar to those outlined in Section 4.1.2.

**Industry noise:** Currently 155 seismic survey vessels operate throughout the world with source levels of up to over 260 dB re 1  $\mu$ Pa at 1 m (far field estimate). Hundreds of naval vessels operate military sonars with source levels of 240 dB. Most data on effects of noise on cetaceans stems from research on dolphins and pinnipeds. This creates the necessity of extrapolating from these well known species to less studied species such as deep diving sperm and beaked whales. However, findings such as a possible link between mass strandings of beaked whales and operations of naval sonars (Simmonds and Lopez-Jurado 1992; Frantzis 1996), the observed variability of sperm whale behavior in response to sound (Madson and Mohl 2000, Watkins and Schevill 1975; Watkins *et al.*, 1985), and possible whale avoidance of loud seismic vessels at great ranges (Bowles *et al.*, 1994; Mate *et al.*, 1994) suggest that more data is needed, especially specific to these deep diving species. As long as powerful sound sources are operated in or near deep waters, deep diving marine mammals are being exposed and the No Action Alternative

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would prevent the acquisition of information critical for protecting these animals from the potential adverse effects of noise.

**Assessment of low power sonar to detect marine mammals:** Some sound sources are so intense that they create a risk of injuring animals that are too close. The zone of potential injury may measure hundreds of meters from some sources (Richardson *et al.*, 1995). This creates a need to monitor to ensure that no animals are in this potential zone of injury. It has been increasingly recognized that current visual and passive acoustic monitoring techniques are not 100% effective for this monitoring task. This recognition has led to considerable recent effort to develop low power, mid-high frequency active sonar that can detect marine mammals or sea turtles within a range of 1-2 km. Both validation of the effectiveness of this whale-finding sonar and testing to ensure that they do not elicit adverse reactions in marine mammals are essential if this kind of sonar is to be used to improve monitoring to mitigate the impact of intense sound sources. Although Dr. Tyack would be authorized to conduct some tests of whale-finding sonar under his current permit (981-1578), the source levels authorized have already been tested and found to be ineffective for generating imaging echoes of marine mammals. Thus, under the No Action Alternative, neither useful validation of the effectiveness of these sonars in detecting marine mammals nor relevant testing for marine mammal reactions would occur.

**Computer modeling of behavior:** In many fields of science, computer modeling may provide an alternative to expensive or risky empirical studies. It may be possible to combine computer modeling with imaging of the auditory structures of deep diving marine mammals in order to predict sound exposure factors that may cause auditory damage. However, such modeling cannot predict behavioral responses of deep divers at sea. Behavior is extremely difficult to predict and poorly studied species such as beaked whales may, for unknown reasons, be much more or less likely to have adverse behavioral reactions than the better studied species. The only way to test whether exposure factors thought to be safe actually do not evoke adverse behavioral reactions is to expose animals to a carefully controlled series of increasing exposures, monitoring behavior in detail. This would not be conducted under Alternative 1.

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Similarly, little is known about the Target Strength of marine mammals in regards to whale-finding sonar, especially as it varies with species, size and orientation in the water column, and computer modeling may not be able to replace empirical research collected in the field.

Although Dr. Tyack would be authorized to conduct some tests of whale-finding sonar under his current permit (981-1578), the source levels authorized in that permit have already been tested and found to be insufficient to generate imaging echoes of marine mammals. Thus, under the No Action Alternative, no new information on the target strength of marine mammals nor any progress on the development of a whale-finding sonar that could be used for mitigation would be occur.

**Observation of industrial operations:** Currently, the man-made sound sources of greatest concern for deep diving marine animals are seismic and high-powered (mid frequency) military sonar operations. Such sources are operated to optimize geophysical or military objectives. However, observing such operations to study responses of animals so that similar exposures can be pooled for statistical analysis is difficult. Behavior may vary by individual, so it is important to obtain pre-exposure and exposure data from the same individuals, but this is often difficult if the biologists cannot control the sound source (Green *et al.*, 1994; Popper *et al.*, 2000). Ongoing active sound operations may also bias the pool of potential subjects for studies. The animals remaining in an area where intense sound sources have been operated for a long time may be a subset of the population that for some reason does not avoid the sounds (*e.g.*, have habituated to the sound, are more strongly attracted to the area for food, mates, etc.). Studies attempting to correlate intensity of these acoustic activities with obvious biological measures such as distribution at sea or strandings are difficult. Even the most intense and carefully planned studies with good cooperation from industry have generally been inconclusive (Richardson *et al.*, 1987). These correlative studies usually lack geographical replication and control data from undisturbed areas. In uncontrolled studies it is difficult to discriminate whether behavioral changes are due to naturally occurring or experimental variables. Also, these animals spend much of their lives beneath the surface, and behavioral reactions to the sound source may occur

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at depth where visual observers cannot detect the reaction. Carefully controlled experiments are usually required to show causation and to establish safe exposure factors. The proposed research would establish an experimental protocol to monitor responses of tagged deep divers to controlled exposure of noise. Thus, the No Action Alternative would perpetuate the present situation in which the production of intense underwater sound is always accompanied by uncertainty about whether the sound is affecting the behavior of marine mammals in a significant way.

The No Action Alternative would do nothing to improve the information currently available on which to base policy decisions in regards to the effects of noise on various marine mammal species

#### **4.1.2 Effects of Alternative 2 - Proposed Action**

##### *Potential effects of tagging and vessel approach*

It is not expected that the close approaches for tagging and focal follow, nor the actual use of the suction-cup tag, will have lasting negative effects on the animals. As mentioned above, these procedures have been analyzed by NOAA Fisheries in several previous EAs and biological opinions and been found to result in no significant impact to the animals. These research methods have been used and evaluated by many different researchers over the years. Close approaches are routinely employed as a method of biopsy sampling, tag attachment, to obtain photographs, or to collect behavioral data on marine mammals, often with minimal or no reaction by the animal. The researchers propose to attach non-invasive tags to a variety of cetacean species as parts of all three research projects. The DTAGs are non-invasive, use soft suction cups, and there is no indication that they cause any pain to the tagged animal. If the tag bothers an animal, it can easily shake off the tag by rolling or shaking movements. A minority of the tagged animals do this. The ease and speed with which they can remove the tag if they are sensitive to it indicates little chance for stress from attachments. Sperm whales in the Gulf of Mexico and pilot whales in the Mediterranean have been tagged with tags similar to those proposed here with no adverse impacts. The tagging protocol involves careful observation of

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potential behavioral reactions to the approach of the tagging vessel and to the actual tag attachment. Attempts to tag a particular individual will be terminated: (1) if the animal shows an adverse reaction to the proximity or behavior of the tagging vessel; or (2) after the third failed attachment attempt. A separate observation vessel will record the animal's behavior during all approaches, tag attachment, as well as post-attachment. Using Weinrich *et al.*'s (1991) classification of responses to biopsy sampling, four potential levels of reaction may be documented: (1) no reaction (no detectable behavioral change); (2) low-level reaction (slight, mild behavioral change, e.g., flinch or fast dive, short duration); (3) moderate (forceful behavioral change, e.g. breach, short duration); or (4) strong (succession of "forceful activities). To mitigate potential disturbance, further tagging attempts on a particular individual will be discontinued if a moderate or strong reaction is observed to an attempt. Each approach for tagging only lasts a few minutes, and no individual will be approached more than three times.

*Potential effects of sperm whale coda playbacks*

Dr. Tyack proposes to play recordings of sperm whale codas as a control stimulus in both Projects 2 and 3. Codas are vocalizations that are not used for echolocation and are thought to be for social purposes. Sperm whales occur in both the Mediterranean and the Gulf of Mexico where the playbacks are proposed. Thus, these sperm whale sounds will not constitute a novel stimulus in these environments. Also, as sperm whales feed chiefly on squid and do not prey on other marine mammals, it is not expected that the sperm whale codas will elicit any negative behavioral response from any other species of marine mammals.

*Potential effects of whale-finding sonar and airgun acoustic experiments*

This section presents information on the ability of marine mammals, endangered sea turtles, and fish to hear and produce sounds and the potential behavioral and physical auditory effects of the sounds transmitted in the proposed research on these and other marine animal species that may be encountered. The following brief description of terms will facilitate understanding of the acoustic effects discussion.

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Hearing threshold: The level of sound that is barely audible in the absence of significant ambient noise is the absolute hearing threshold. It is the lowest sound level that is detected during a specific percentage of experimental trials. A statistical definition is necessary because, even for a single animal, the minimum detectable sound level varies over time (Richardson *et al.*, 1995).

Best frequency: The best frequency is the frequency with the lowest hearing threshold for a particular species, that is, the best sensitivity (Richardson *et al.*, 1995).

Direct Damage to Major Hearing Structures: Extreme types of hearing effects are pressure-induced injuries associated with explosions or blunt cranial impacts that cause an eruptive injury to the inner ear (frequently coinciding with fractures to the bony capsule of the ear or middle ear bones and with rupture of the eardrum or round window). These injuries are not acoustically-induced, thus, this kind of damage will not occur under the proposed research.

Permanent Threshold Shift (PTS): an increase in the threshold of hearing that is permanent, not temporary. It is an unrecoverable deafening due to physiological damage to the hearing organs that does not diminish with time. PTS may occur as a result of long-term exposures and/or extremely loud noises. Repeated exposures that cause temporary threshold shift (TTS) can induce PTS, as well. The mitigation measures proposed for implementation under the proposed research and discussed in the EA are designed to ensure that PTS does not occur from experiments under the proposed research.

Temporary Threshold Shift (TTS): a brief, transitory increase in an individual animal's hearing threshold in response to exposure to sound. All humans typically experience such shifts, such as the effect that occurs after leaving a noisy room for a quiet location. For a period of time, hearing sensitivity is decreased such that quiet sounds are not perceived. TTS recovers so that original hearing abilities return. Minor amounts of shift (3-5 dB) may recover in minutes; large shifts (40 dB) may recover overnight, and major shifts (>45 dB) may require days or weeks to recover. Above 65 dB the shift may not fully recover. TTS generally occurs in a limited or

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affected frequency band at sound intensities well above hearing threshold levels. Using NOAA Fisheries interim guidance (based on human hearing data), the difference between the threshold of hearing and sound intensities that result in annoyance (or possibly TTS) in marine mammal is approximately 80 to 100 dB. For the experiments covered by this assessment, the more conservative value of 80 dB above threshold will be used throughout. NOAA Fisheries nevertheless notes that at this time, exposures that cause PTS or TTS have not been measured for mysticetes or sperm whales.

Behavioral Response and Habituation: Sounds can result in short-term behavioral responses that range from changes in movement patterns that can only be detected through sophisticated statistical analysis, to more dramatic actions such as marine mammal breaching, rapid swimming, and temporary or permanent displacement from an area. Response is not narrowly predictable and can vary with sex, age, social context and season. Infrequent and minor changes in movement directions, for example, may be completely benign, while recurrent incidents of interrupted feeding and rapid swimming, if sufficiently frequent and of prolonged duration, could have negative effects on the well-being of individuals. Behavioral changes generally are detected at sound intensities higher than the levels at which masking (see below) could occur.

Masking: Increases in noise levels can decrease the ability of an animal to detect biologically important sound when the increased noise level rises above the level of sound for which the animal is listening. This effect is commonly known as masking. Masking of significant sounds (*e.g.*, calls of other animals, predators, sounds of hazards, such as approaching boats, etc.) can occur when ambient noise levels increase. Marine mammals have evolved in the highly variable noise environment of the ocean, and presumably are well adapted for tolerating the natural variations in ocean noise that could at times cause masking. However, the determination of an animal's ability to tolerate changes in noise levels requires a better understanding of: 1) the functional importance of faint sound signals from the same species, predators, prey, and other natural sources; 2) signal detection abilities of marine mammals in the presence of background noise, including directional hearing abilities at frequencies where masking is an issue; and 3)

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abilities of marine mammals to adjust the intensities and perhaps frequencies and timing of emitted sounds to minimize masking effects.

Loud noise has been shown to have several negative impacts upon animals: tissue damage, hearing loss, physiological stress, and interference with normal activities and behavior. Most impacts appear to scale with acoustic energy and with duration of exposure. Richardson *et al.* (1995; Chapter 10) developed a model for different zones of noise influence, from zone of audibility, zone of masking, to zone of responsiveness, and zone of hearing loss, discomfort and injury. This section will be focusing upon physical effects on audition, and behavioral effects such as masking and disruption of normal behavior.

Exposure to high energy sound (where energy is a combination of received level and the sound duration) can cause physiological damage. The blast exposure thought to be safe for protecting humans underwater from injury to the digestive tract is pulses of 10 psi-msec and peak pressures of 237 dB re 1  $\mu$ Pa (Gaspin 1983). ONR (1999:65) cites (Turpenny *et al.*, 1994) stating that the lack of gas-filled cavities in most invertebrates and fish without swimbladders make the risk of injury low at exposure levels <217 dB re 1  $\mu$ Pa. Swimbladder fish and marine animals with lungs are thus among the marine organisms most sensitive to intense pulses of sound energy. Blast-induced pressure waves may kill swimbladder fish at ranges of up to several km. Very little has been published about these non-auditory blast effects on marine mammals. Hemorrhage in the lungs and contusion and ulceration of the gastro-intestinal tract were detected in experiments where submerged terrestrial mammals were exposed to underwater explosions at close range. These effects occur at lower exposure factors for smaller animals than for larger ones.

Exposure to blast with peak pressures > 237 dB re 1  $\mu$ Pa caused lethal lung injury in sheep (Fletcher *et al.*, 1976). Exposing swine to levels of 191-214 dB re 1  $\mu$ Pa for 30-90 sec caused slight lung injury (Percy and Duykers 1978). Exposure to man-made noises has been associated with auditory damage in some marine mammals. For example, damage to the inner ear was

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observed in Weddell seals, *Leptonychotes weddellii*, collected from McMurdo Sound, Antarctica shortly after a series of dynamite explosions. The locations of these seals during the explosions and their exposure levels were unknown. Of ten cochleas that could be examined, five were found to be damaged. Degeneration of the organ of Corti and corresponding damage to the eighth cranial nerve were observed (Bohne *et al.*, 1985, 1986). Blast damage to the auditory system of humpback whales has also been documented by Ketten *et al.* (1993). These whales were in the vicinity of underwater blasts from 5000 kg of high explosive, but their exposure level and duration were unknown.

However, none of the sounds used in the proposed experiments have the kind of impulse waveform associated with blast damage, and none are intense enough or of long enough duration to likely cause non-auditory damage. Therefore, discussion will be limited to potential physical effects on the auditory system, which may occur at lower exposure factors.

The auditory system is designed for efficient transduction of sound energy, so loss of hearing typically occurs at much lower noise levels than would cause damage to other tissues. This has led the U. S. Environmental Protection Agency to use protection against hearing loss as the standard to regulate noise exposure. Exposure of humans to high sound levels can accelerate the normal process of gradual permanent hearing loss with increasing age (Kryter, 1985).

Immediate PTS can be caused by exposure to short duration sounds 155 dB over threshold (Kryter, 1985:272). PTS can also be caused by long-term exposure to sound. In humans, temporary shifts in hearing thresholds measured after an 8-hour exposure to noise are used to approximate the permanent threshold shift that would occur after long-term exposure to the same level in the workplace. Chronic exposure to noise roughly 80 dB or more above the threshold of hearing can lead to hearing loss in humans. Risk of TTS decreases with shorter exposures. The criteria for humans proposed by Kryter *et al.* (1966) are 82 dB above threshold for 2 hours/day; 88 dB for 30 min/day; 98 dB for 7 min/day; 115 dB for 1.5 min/day. Limiting exposure to <80 dB above the hearing threshold is thought to protect human hearing during exposure to continuous noise in air. Richardson (1995) calls this the "80 dB above threshold" rule. The

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extent to which results on noise-induced hearing loss in terrestrial species can be applied to aquatic species is not well understood by scientists.

Ketten (1994 and 1995) reviews current knowledge about acoustic trauma in terrestrial mammals with data on the anatomy of the ears of marine mammals as a framework to discuss effects of noise exposure on marine mammals. The following is a summary of her analyses: Marine mammals are acoustically diverse with wide variations in ear anatomy, range, and sensitivity. Like land mammals, dolphins, whales, and seals have ears that are essentially a fluid-filled bony spiral containing a resonating membrane and a series of frequency-pressure-energy detectors. With this basic mammalian auditory anatomy, some animals (*e.g.*, dolphins) hear well into the ultrasonic range ( $>20$  kHz), while others (baleen whales) hear well into the infrasonic range (50 Hz). Frequency ranges differ for each species based largely on differences in stiffness and mass of middle and inner structures. There are also important differences among species in their sensitivity in any frequency band. Marine mammals have both large hearing ranges and specialized ear structures adapted to the acoustic characteristics of water rather than airborne sound. Their middle and inner ears are heavily modified from terrestrial mammal ears to accommodate rapidly changing pressures encountered in deep dives, and acoustic power relationships several magnitudes greater than in air. These adaptations may lessen the risk of injury from high intensity noise in some species.

A key component of whether or not a given source will cause hearing loss is an animal's ability to hear the frequencies of that sound source. Virtually all studies show that the extent of hearing loss from a non-impulse sound depends on the frequency sensitivity of the animal. For impulse sounds, like explosions, the frequency of the sound is of less concern and it is the response of the ear membranes to the fast rise time that is more important. For pure tones and narrow band sound sources of short duration (*e.g.*,  $<1$  hr), threshold shifts should occur at or a half octave above the frequency of the stimulus. Any hearing impairment that may occur at frequencies outside these ranges would be expected to be much less pronounced, unless the stimulus continues for very long time periods (*e.g.*, a hydroelectric power plant generator) or rapidly

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reaches an exceptionally high intensity. The sounds to be used in the proposed experiments do not match these exposure characteristics.

### **Cetaceans -Mysticetes (Baleen whales)**

There are no direct measurements of auditory thresholds in mysticetes. However, studies suggest that they are adapted for hearing at low frequencies (below 1 kHz) and that they likely hear best in the frequency range of their calls (Evans, 1973; Myrberg, 1978; Ketten, 1994). Baleen whales' vocalizations range from 8-11 Hz (Clark, 1996) with principal energy in the 100-300 Hz band (Clark, 1990). At least 10 of the 11 extant species of mysticetes produce some form of low frequency sound below 400 Hz (Thompson, Winn, and Perkins, 1979; Watkins and Wartzok, 1985; Clark, 1990). Baleen whales may avoid pulses from airgun arrays at received levels of about 170 dB re 1  $\mu$ Pa and ranges up to about 10 km (Malme *et al.*, 1985; McCauley *et al.*, 1998). These observations suggest that baleen whales may show some avoidance behavior to airgun or sonar sounds, which is likely to limit the received levels to which they are exposed. However, this avoidance does not appear to be accompanied by disruption of other behaviors such as diving or vocalization, and exposures and responses would be limited to a few hours. Humpback, fin, and right whales have been reported to respond to sonar sounds in the 15 Hz – 28 kHz range (Watkins 1986).

#### *Potential for physical auditory effects:*

There are no audiograms (*i.e.*, direct measurements of the auditory thresholds) for mysticetes, nor are there data on what sound exposure may cause TTS or PTS in mysticetes. It is therefore necessary to extrapolate from data from other animals, and to make assumptions about hearing. The following assumptions are used in deriving a threshold for potential auditory effects:

- TTS and PTS in marine mammals occur at intensity-duration limits similar to those in land mammals
- Immediate PTS can be caused by exposure to sounds 155 dB over threshold
- TTS to a signal >80 dB over threshold requires prolonged exposure (8 hours/day)
- Risk of TTS decreases with shorter exposures. Human criteria: 82 dB for 2 hours/day; 88

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dB for 30 min/day; 98 dB for 7 min/day; 115 dB for 1.5 min/day. All dB values above threshold.

- The critical band of hearing is about 1/3 octave

The best hearing for odontocete cetaceans where hearing has been tested is about 40 dB re 1  $\mu$ Pa. This is typically at frequencies > 10kHz, where the ambient noise at Beaufort Sea State 0 has an average third octave band level of about 60 dB re 1  $\mu$ Pa. Ambient noise levels are higher at lower frequencies. Even if baleen whales are adapted for lower frequency hearing, their hearing may have evolved to have a similar sensitivity with respect to the ambient noise. The third octave level for 1 kHz at Beaufort Sea State 0 is about 70 dB re 1  $\mu$ Pa. Ketten (1998) suggests that the sensitivity of baleen whales at low frequency is unlikely to be lower than 80 dB re 1  $\mu$ Pa.

Assuming the above assumptions are either correct or conservative, then baleen whales might experience PTS after exposure to sounds  $80+155 = 235$  dB or more re 1  $\mu$ Pa. There might be some risk of TTS from very prolonged exposure of animals to received levels of sounds at > 160 dB re 1  $\mu$ Pa. In the proposed experiments, it is very unlikely that any baleen whale would be exposed to received levels > 160 dB for more than a few pings on one day. NOAA Fisheries believes that it is unlikely that any of the mysticetes would experience significant effects, based on the fact that their exposure to the sounds used in these experiments would be brief, and that focal animals are likely to be ensonified only for one experiment for a brief period.

#### *Potential for masking:*

Masking processes in baleen whales are not amenable to laboratory study and no data on hearing sensitivity are available for these species. It is not currently possible to determine with precision the potential consequences of temporary or local background noise levels. For species that can hear over a relatively broad frequency range, as is presumed to be the case for mysticetes, a narrowband source may only cause partial masking. Furthermore, the signals to be transmitted in the proposed research will last only tens to hundreds of msec at a maximum duty cycle of 3%.

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The summed durations of the transmissions will be less than those of a passing super tanker, which produces noise continuously. The proposed research will have a very low duty cycle, meaning that the masking sound will not be present most of the time. In light of the low number of mysticetes that may be exposed and the relatively brief duration of the transmissions, masking effects are presumed to be insignificant, and less than the potential impact of a passing ship.

*Summary:*

Baleen whales are not likely to experience TTS from the proposed activities because received levels will be too low to cause immediate TTS and the durations of the exposure periods are too short to yield prolonged exposure TTS. Masking effects should be minimal due to the short transmission period of the sounds. The biological opinions written for Dr. Tyack's current permit (No. 981-1578) concluded that the proposed tagging, whale-finder sonar tests, and airgun playbacks were not likely to affect the endangered blue, fin, humpback, or sei whales in a way that reduces their reproduction, numbers, or distribution, and therefore, is not likely to appreciably reduce their likelihood of surviving or recovering in the wild.

**Cetaceans -Odontocetes (Toothed whales and dolphins)***Potential effects of sound transmissions:*

As with mysticetes, the proposed action may have the potential to adversely affect odontocetes, directly and/or indirectly, as a result of sound transmissions. A description of the species of odontocetes expected to be found in the proposed research areas is found in Section 3.3-3.4. Many dolphin species show little reaction to operating airguns, but some may show behavioral effects within a range of about 1 km (Goold and Fish 1998). Captive bottlenose dolphins do not show aversive reactions to 1-sec tonal signals until the received level is above 180 dB re 1  $\mu$ Pa (Schlundt *et al.*, 2000). This would correspond to a range of no more than 1 km from an airgun array and less than 100 m from the whale-finder sonar. Rendell and Gordon (1999) recorded pilot whales in the presence of 0.17 sec pings from a 4-5 kHz sonar. The pilot whales vocalized more often during transmissions, but did not avoid the area during several hours of exposure. The observed responses of odontocetes to airguns and sonar appear to be limited to a range of between 100-1000 m, a range within which they can be monitored visually by the visual

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observers who are always on watch before, during and after transmissions. Any changes of vocal behavior, such as that reported for pilot whales, can be detected by the passive acoustic monitors.

*Potential for physical auditory effects:*

Odontocete species on which underwater audiograms have been published include the killer whale (down to 500 Hz), false killer whale (down to below 1 kHz), beluga (down to 40 Hz), harbor porpoise (down to 1 kHz), Amazon River dolphin (down to 1 kHz), bottlenose dolphin (down to 75 Hz), Risso's dolphin (down to 75 Hz), and Pacific white-sided dolphin (down to approximately 90 Hz) (Johnson, 1967; Awbrey *et al.*, 1988; Johnson *et al.*, 1989; Nachtigall, Au and Pawlowski, unpubl., 1996; Thomas and Tremel, unpubl. 1996). The best sensitivities of these animals at 12 kHz is about 40 dB re 1  $\mu$ Pa. At 1 kHz, best sensitivities are about 80 dB re 1  $\mu$ Pa. Ridgway *et al.* (1997) tested bottlenose dolphins to see what exposure factors could cause temporary threshold shifts for one second signals. Frequencies of 3, 20 and 75 kHz yielded masked TTS at exposures (received levels) ranging from 192-201 dB re 1  $\mu$ Pa (*i.e.*, 115-150 dB above hearing threshold).

There are no published audiograms of the sperm whale. Because of its size, the sperm whale might be expected to have good low frequency hearing; however, its inner ear resembles that of most dolphins, and appears tailored for ultrasonic (>20 kHz) reception (Ketten 1994). There are, however, indications that sperm whales may have hearing capability at low frequencies (Carder and Ridgway 1990), and they are known to be sensitive to changes in manmade mid frequency transient sounds (Watkins *et al.*, 1985). The best hearing for odontocete cetaceans where hearing has been tested in the laboratory is about 40 dB re 1  $\mu$ Pa. This is typically at frequencies > 10kHz, at those frequencies the ambient noise at Sea State 0 has a third octave band level of about 60 dB re 1  $\mu$ Pa. Ambient noise levels are higher at lower frequencies. Even if sperm whales are adapted for lower frequency hearing, their hearing may have evolved to have a similar sensitivity as dolphin species with respect to the ambient noise. The third octave level for 1 kHz at Beaufort Sea State 0 is about 70 dB re 1  $\mu$ Pa. This is relatively close to delphinid

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best sensitivities at 1 kHz, which are about 80 dB re 1  $\mu$ Pa. The above discussion would suggest that even if sperm whales can hear lower frequencies than dolphins, they may be expected to have a similar sensitivity at 1 kHz near 80 dB re 1  $\mu$ Pa.

The above, including limitations on received level at the animal, the low duty cycle in which sounds are transmitted <3% of the time during a playback, and the limited time duration (several hours) of sound playbacks for research activities, suggests that the potential for physical auditory impact on odontocetes, including the listed endangered sperm whale should be minimal.

*Potential for masking:*

As noted previously, no specific information is available about the nature and effects of masking for odontocetes under field conditions, and little is known about the adaptations that marine mammals may use to reduce masking. Studies on captive odontocetes by Au *et al.* (1974 and 1985) indicate that some species may use various processes to reduce masking effects (*e.g.*, adjustments in echolocation call intensity and/or frequency as a function of background noise conditions).

The sounds produced by sperm whales are broadband and center around two frequency bands, 2-4 kHz and 10-16 kHz (Backus and Schevill, 1966). Recent work suggests that their echolocation signals may involve even higher frequencies (Møhl *et al.* 2000). The proposed transmissions occur in much narrower bands than this. Therefore, it is unlikely that the proposed transmissions would interfere with, or mask, normal sperm whale sounds. All dolphin species which might be encountered in the research areas are thought to vocalize and hear well at high frequencies. The limited bandwidth of the playback signals used in the proposed research is unlikely to mask the full bandwidth of these animals' vocalizations. The 1-12 kHz transmissions proposed here for the whale-finding sonar last less than 1 sec and are only transmitted at a rate of 1/15 sec. Airgun impulses only last tens of msec and are typically transmitted at a rate of about 1/10sec. The odds that these short signals will happen to occur at exactly the same time as sperm whale clicks is very low. The proposed sound transmissions are very brief and therefore, minimal, if any,

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masking impacts would be expected on these species from exposure to the transmissions proposed here.

*Summary:*

The short durations of the sound transmissions proposed in Projects 2 and 3 as well as the high levels required to achieve TTS in odontocetes suggest that these playbacks should have only minimal impact on toothed whales and dolphins. The acoustic characteristics of sperm whale clicks and dolphin vocalizations combined with the brief duration of the sound transmissions suggest that the potential for the proposed research to cause masking will be low. A biological opinion written for Dr. Tyack's current permit (No. 981-1578) found that the proposed tagging, whale-finder sonar, and airgun playbacks were not likely to affect the endangered sperm whale in a way that reduces their reproduction, numbers, or distribution and therefore, is not likely to appreciably reduce their likelihood of surviving or recovering in the wild.

**Pinnipeds**

The only Mediterranean pinniped is the highly endangered Mediterranean monk seal. The odds of encountering a Mediterranean monk seal in the Ligurian Sea are very low. Based on these data and the low probability of these animals in the proposed research area, and including the fact that the average duty cycle for research activities will be low and intermittent, the potential for physical auditory effects or masking on pinnipeds should be minimal. As there is no extant species of pinniped in the Gulf of Mexico, therefore no pinnipeds should be exposed to the acoustic experiments there.

**Florida manatee**

The hearing sensitivity of the West Indian manatee was determined by behavioral testing to range from 15 Hz to 46 kHz, with best sensitivity at 6-20 kHz (Richardson *et al.*, 1995). Manatee calls are below 10-12 kHz, and the manatee was reportedly more sensitive below 3 kHz than any other marine mammal tested to date. Manatees are not found in the Mediterranean and thus will not be exposed to whale-finding sonar during Project 2. Furthermore, based on the nearshore range of manatees in the Gulf of Mexico and the deep water focus of the proposed

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research, it is unlikely that any manatee will be exposed to airgun sounds associated with Project 3.

### **Sea turtles**

Endangered sea turtles are present in both the Mediterranean and the Gulf of Mexico where playback experiments are planned. Sea turtles have well-developed ears, and several studies suggest that they can hear sounds below 1 kHz, but no evidence suggests that they can hear higher frequencies. However their auditory sensitivity is poor.

#### *Potential for physical non-auditory effects:*

Sea turtles have lungs, which constitute a tissue boundary that may be affected by underwater sound, so turtles are potential candidates for acoustic damage. However, the source levels proposed for this research are well below those thought to pose a risk of lung damage.

#### *Hearing capabilities of sea turtles:*

Studies of hearing in juvenile loggerhead sea turtles suggest that they can hear frequencies between 250-750 Hz, with best hearing at 250 H (Bartol *et al.*, 1999). Green turtles are most sensitive to frequencies of 300-400 Hz, but their sensitivity declines rapidly outside of this range (Ridgway *et al.*, 1969). Ridgway *et al.* (1969) used aerial and mechanical stimulation to measure the cochlear response in three specimens of green sea turtle, and concluded that they have a useful hearing span of perhaps 60-1000 Hz, but hear best from about 200 Hz up to 700 Hz, with their sensitivity falling off considerably below 200 Hz. One turtle with a 400 Hz frequency best hearing sensitivity showed a hearing threshold of about 64 dB in air (approximately 126 dB in water, if one corrects for the differences in acoustic impedance between air and water and the different ways sounds in air and water are referenced). Lenhardt *et al.* (1983) applied audio frequency vibrations at 250 Hz and 500 Hz to the heads of loggerheads and Kemp's ridleys submerged in salt water. At the maximum upper limit of the vibratory delivery system, the turtles exhibited abrupt movements, slight retraction of the head, and extension of the limbs in the process of swimming. Lenhardt *et al.* (1983) concluded that bone-conducted hearing appears to be a reception mechanism for at least some of the sea turtle species, with the skull and shell

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acting as receiving surfaces. There are no audiogram data available for leatherbacks. Because they are morphologically distinct, approximating hearing thresholds from data available for the other (hard shell) species is probably inappropriate.

*Potential for physical auditory effects:*

Hearing in turtles has not been studied extensively, but indications are that the turtle ear is relatively insensitive and functions best below 1 kHz. Ridgway *et al.* (1969) reported the lowest threshold to be 64 dB in air (+ 61.5 dB conversion factor = 126 dB under water). TTS has not been studied in turtles. In humans, TTS requires prolonged exposure (8 hrs per day) to a signal >80dB over threshold. Since sea turtle ears are less sensitive to sound than human ears, it is highly unlikely that any turtle would sustain TTS from the proposed sources.

All of the energy from the whale-finding sonar to be tested in the Mediterranean Sea (Project 2) is far enough above the hearing range of sea turtles, that it is less likely that these signals can be heard or would have adverse effects on sea turtles. The majority of energy from airguns (Project 3) is outside of this frequency range of sea turtle hearing. However, airgun impulses are intense enough and broadband enough that sea turtles certainly can hear them. There are no published reports of effects of airguns on sea turtles at sea. However, several studies have reported responses of sea turtles held in enclosures to pulses from single airguns. McCauley *et al.* (2000b) report that a green and loggerhead turtle showed responses that would probably reflect an avoidance response in unrestrained turtles at received levels of 166 dB re 1  $\mu$ Pa rms. O'Hara and Wilcox (1990) studied responses of 9 loggerhead turtles to an airgun plus two small sources called poppers. They did not measure received levels at the turtles, but did avoid a range of about 30 m, which McCauley *et al.* (2000b) estimate to reflect a received level of about 175 dB re 1  $\mu$ Pa rms. Moein *et al.* (1994) studied responses of ten loggerhead turtles to a single airgun, and observed avoidance responses at received levels of 175 – 179 dB re 1  $\mu$ Pa, but did not specify whether these measurements were rms, 0-p, or peak. McCauley *et al.* (2000b) summarize these three studies by suggesting that the behavior of sea turtles may alter at ranges of 2 km corresponding to a received level of 166 dB re 1  $\mu$ Pa and are likely to avoid ranges of 1 km

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corresponding to received levels of 175 dB re 1  $\mu$ Pa. For these reasons, no adverse effects of the proposed research on sea turtles are anticipated. However, to be especially cautious with these endangered species, as a mitigation measure, if the visual observers sight a sea turtle that might come within the maximum exposure region, the source will be shutdown.

*Potential for Masking:*

Any potential role of long-range acoustical perception in sea turtles has not been studied and is unclear at this time. Anecdotal information suggests that the acoustic signature of a turtle's natal beach might serve as a cue for nesting returns. However, in general, sea turtles do not rely on sound like marine mammals do for echolocation and communication. Though sea turtles can probably detect airgun impulses, it is unlikely that the proposed transmissions will interfere with biologically important sound (*i.e.*, masking) for sea turtles.

**Fish**

No adverse effect is anticipated. Of the species preyed upon by marine mammals, swimbladder fish are thought to be the most sensitive to airguns. The seismic industry switched from using explosives to airguns as a sound source in part because airguns do not kill fish. McCauley *et al.* (2000a,b, 2002) and Popper *et al.* (2002) review recent data that injurious effects on fish, especially on fish hearing, may occur to somewhat greater distances than previously thought, but these will still be limited to short distances from the airguns, and reduced by avoidance reactions of fish near airguns. Fish near airguns may show behavioral responses that might reduce the ability of cetaceans to feed near the source (Engås and Løkkeborg 2002). But the source only ensonifies a small part of the habitat, the fish habituate to the sound, and cease responding when the source is turned off.

*Potential for physical non-auditory effects:*

Some fish have swimbladders, which present a tissue boundary that may be affected by underwater sound, so these species are potential candidates for non-auditory acoustic damage. Since the acoustic impedance of air and water are very different, tissues at the boundary of these

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two impedances may become stressed and rupture. Many fish have swimbladders with resonant frequencies within the range of the proposed sound transmissions. For example, a small anchovy at one atmosphere of pressure has a resonant frequency of 1275 Hz (Batzler and Pickwell 1970). However, the sounds in the proposed research are too brief and the source levels are well below those required to set up resonance effects that may pose a risk of swimbladder damage.

*Potential for physical auditory effects:*

Audiograms have been determined for over 50 fish and three shark species (Fay, 1988). The majority of acoustic data have been collected on bony fish, while virtually nothing is known of hearing in jawless fish (Popper and Fay, 1993). Myrberg (1980) states that the most important region of sound detection in most fishes rests between about 40 and 1000 Hz. Sharks generally do not detect sounds above 1 kHz and, in most cases, best sensitivity is to signals below 300 Hz (Popper and Fay, 1977). Sharks seem to be attracted to low frequency sounds which they may use as a means of locating prey. Sensitivity in lemon sharks is best at about 40 Hz (Nelson, 1967; Kelly and Nelson, 1975). Fish that have specialization that enhances their hearing sensitivity have been referred to as hearing specialists, whereas those that do not possess such capabilities are termed nonspecialists. The former tend to have greater sensitivity and a wider hearing bandwidth (up to 3 kHz) than the latter. The squirrelfish, for example, can detect 2 kHz sounds at 105 dB re 1  $\mu$ Pa. Some recent research suggests that fish such as alewives, herring, and cod are able to detect intense high frequency sounds. For example, Astrup and Mohl (1993) provide evidence that cod (*Gadus morhua*) detect short 38 kHz pulses at 194 dB re 1  $\mu$ Pa. Both alewives (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) form tighter schools and moved away from playback of sounds from 110-140 kHz at levels above 160 dB re 1  $\mu$ Pa (alewives; Dunning *et al.*, 1992) to 180 dB re 1  $\mu$ Pa (herring; Nestler *et al.*, 1992). The sound transmissions in the proposed research are lower in frequency than those sounds that elicited behavior response from fish as described above, so the proposed research may not elicit any response from fish species. However, even if fish were to show similar responses to proposed sound transmissions, the observed responses occurred at intense received levels, which in the proposed research would only occur over a very small range close to the sound source.

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Furthermore, ramp up procedures for both the whale-finding sonar and the airgun array should allow fish that can hear and are disturbed by the sounds to move away from the sound source.

McCauley et al. (2000, 2003) show that exposure to airgun signals can damage inner ear hair cells in fish at exposure levels above 180 dB re 1  $\mu$ Pa in the 20-100 Hz band. Hastings (1991) makes some general conclusions from evidence based on a thorough literature search that, in the 50-2000 Hz frequency band, received levels at or above 180 dB would be harmful to fish. Relatively small numbers of individual fish would be expected in this potential hazard zone (within thirty meters of a 210 dB source and within 317 meters of a 230 dB source, assuming spherical spreading). This could only affect an insignificant proportion of any fish population. The potential for physical effects on fish hearing is judged to be insignificant.

#### *Potential for masking:*

Based on the information that fish hearing and vocalizations are primarily below 1 kHz, and the proposed sound transmissions of the whale-finder sonar are > 1 kHz, any masking effects on fish species that may be present in project 2 of the proposed research are expected to be minor. There is overlap in frequency between fish vocalizations and airgun impulses, but the low duty cycle of the airgun signals minimizes the chance for masking effects.

#### **Seabirds**

Seabirds that forage for food at sea by plunging or diving beneath the surface could be exposed to underwater sound. Little is known about hearing in seabirds nor about underwater hearing in any bird species. Dooling (1978) summarizes studies of in-air hearing in birds and notes that behavioral measurements of absolute auditory sensitivity in a wide variety of birds show a region of maximum sensitivity between 1 and 5 kHz. This does overlap with some of the proposed whale-finder sonar transmissions, so it is possible that seabirds diving near the source might hear the transmissions. However, this is unlikely to have an impact because: 1) there are few seabirds in the areas of the Mediterranean where the whale-finder will be tested; 2) there is no evidence seabirds use underwater sound; 3) seabirds spend a small fraction of time submerged; and 4) seabirds could rapidly disperse to other areas if disturbed.

### **Invertebrates**

Few invertebrates have tissues with acoustic impedance different enough from seawater to pose a risk of non-auditory damage. Therefore there is likely to be little risk of non-auditory physical damage.

#### *Hearing capabilities and sound production of invertebrates:*

Little is known about the importance of underwater sound in invertebrates. Many invertebrates are not capable of hearing or producing sounds; in fact, no hearing organs or vocal organs have been identified for most species. However, according to Hawkins and Myrberg (1983), it appears that some sound-producing invertebrates are capable of communicating with each other.

The only invertebrates for which thresholds for hearing have been measured are cephalopods and decapods. Budelmann and Young (1994) found a threshold of 146 dB for cephalopods and Offut (1970) found a threshold of 150 dB for American lobster (*Homarus homarus*). Both of these studies found sensitivity to sounds lower in frequency than those to be transmitted in the proposed research. The thresholds are so high that these species would only be able to detect the transmissions within 1 km of the source for the whale-finder sonar and about 10 km for airguns. This is such a small area in which the sounds can even be detected that it is likely to have insignificant effects on invertebrate populations.

### **Human divers**

The U. S. Navy's Bureau of Medicine and Surgery has issued interim guidance for operation of low frequency sound sources (BUMED, 1995). The guidance was derived from a review of many sources, including several Navy-sponsored studies (Pestorius *et al.*, 1996). No studies found physiological evidence of damage for underwater exposures at received levels < 157 dB re 1  $\mu$ Pa. In one study, out of 87 divers and 453 exposure sequences, there was only a single event of a compromised diver (*i.e.*, safety of diver jeopardized), which followed a prolonged (12-15 mm) continuous exposure at a sound pressure level (SPL) of 160 dB re 1  $\mu$ Pa. Guidance recommended for exposure of active duty Navy-trained divers to low frequency waterborne

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sound is: Maximum SPL: 160 dB re 1  $\mu$ Pa; Frequency range: 160-320 Hz; Continuous exposure limit: 100 s; Maximum duty cycle: 50%; Cumulative exposure limit: 15 min/dive day (no more than 9 days exposure per 2-week period).

Data concerning non-auditory effects on divers is limited. Swept tones were felt by the divers at frequencies corresponding to lung resonance (about 70 Hz), but not at higher (or lower) frequencies. Divers subjected to levels of 140 dB in the 30-200 Hz band produced no observed ill effects above 100 Hz. Additionally, divers working in the vicinity of a drilling barge are routinely exposed to broadband, pulsating sound in the low frequency band up to 147 dB without any observed ill effects (Smith and Marsh, 1993). Also, the Naval Submarine Medical Research Laboratory has recommended interim limits, based only on auditory response, which were accepted by the U. S. Navy Bureau of Medicine and Surgery in 1982. These limits state that for auditory effects, 160 dB is well-tolerated for extended periods.

Also in the non-auditory area, Nedwell and Parvin (1996) gave results of diver studies in which subjects reported a mask/sinus effect at approximately 100 Hz with a further low frequency thoracic/body resonance at 25 Hz producing a strong sense of vibration. They concluded that uninformed divers, at depths down to 50 m, may be disturbed at frequencies of 300 Hz when the Received Level is 160 dB. Another study (Schlichting *et al.*, 1996) found that physiological effects (tingling, numbness, vibrations) were reported from a number of immersed subjects. The mean vibration intensity reported at a Received Level of 160 dB was 2.2 on a scale of 1 (mild) to 5 (severe). Only brief persistence of the sensations was observed after the 160 dB sound was turned off. The study concluded that acute exposures to low frequency sound as high as 160 dB re 1  $\mu$ Pa were well tolerated. Work at the Navy Experimental Diving Unit (Clark *et al.*, 1996) concluded that no prolonged adverse vestibular aftereffects were detected in divers exposed to 15 min of cumulative low frequency sound (240-320 Hz) at 160 dB re 1  $\mu$ Pa, although one subject had transient unsteadiness immediately post exposure. Stevens *et al.* (1996) subjected 87 individuals to high intensity (up to 196 dB) sound levels, focusing on both auditory and non-auditory effects.

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Subjective tolerance limits were reached during 12 exposures at 160 dB or greater. Non-auditory effects were cited as reasons for termination during 7 exposures. This study concluded that underwater sound at levels less than 160 dB re 1  $\mu$ Pa were well tolerated for frequencies between 125 and 6,000 Hz. Further, an informal literature review by the Navy (NEHC, 1997) revealed that adequate research on the effects of low frequency sounds on other than the alerted Navy-trained diver does not exist, and that information on acceptable low frequency sound field exposure factors for civilian divers was lacking. A new study was therefore conducted by the Naval Submarine Medical Research Laboratory on safe exposure limits for commercial and recreational divers to sounds of 100-500 Hz. Two percent of the divers in this study had a severe aversion reaction to exposure to 148 dB of underwater low frequency sound. The US Navy has therefore adopted a criterion for SURTASS LFA only that for unalerted civilian divers, received levels in excess of 145 dB should be considered the limits of exposure. The large difference between the Navy guidance level of 160 dB for alerted Navy divers and this level of 145 dB was intended to account for any possible physical conditioning, health and psychological differences between active duty Navy-trained divers and commercial or recreational divers. The U. S. Navy Bureau of Medicine and Surgery has agreed to a Received Level criterion of 145 dB for areas where civilian divers might hear SURTASS LFA sounds.

For the loudest sound transmissions of the proposed research, the expected maximum range for the 160 dB zone is well within the range of visibility for the source ship to see any dive vessels. The sources will not be operated if there is a chance of exposing divers to received levels higher than this criterion.

#### **4.2 Unavoidable Adverse Effects**

The approach of the research vessel and associated noise, may cause disturbance to the whales or dolphins and temporarily interrupt normal activities such as feeding and mating. The effect on the animals is not expected to exceed level B harassment, as defined under the MMPA (see footnote 1), or to have a significant long-term effect on individuals or the population. In other

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words, while individual whales or dolphins may exhibit temporary startle and evasive behaviors in response to the activities of researchers, the impact to individual animals is not likely to be significant because the reactions will be short-lived.

The mitigation measures imposed by permit conditions are intended to reduce, to the maximum extent practical, the potential for adverse effects of the research on the targeted species as well as any other species that may be incidentally harassed. However, as described above, individual animals may experience, to varying degrees, discomfort, pain, and stress as a result of the research activities. The degree to which an individual animal experiences stress or other physiological effects is dependent on a variety of factors including, but not limited to, age (young animals may be more susceptible to stress and injury), breeding status (lactating females may be more likely to react negatively to disturbance), and overall health. Because the research involves wild animals that are not accustomed to being approached, the presence of researchers and vessels will unavoidably result in harassment of some animals. Because it is often difficult to assess the health status of an animal from a distance, or based on visual cues alone, it would not always be possible to determine, in advance, whether an individual dolphin or whale is compromised and therefore predisposed to react negatively to the stress of close approach, tagging or acoustic playbacks.

#### **4.3 Cumulative Effects**

Animals inhabiting the marine environment are continually exposed to many sources of sound. Naturally occurring sounds such as lightning, rain, subsea earthquakes, and animal vocalizations (e.g., whale songs) occur regularly. There is evidence that anthropogenic noise has increased the ambient level of sound in the ocean over the last 50 years. Much of this increase is due to increased shipping as ships become more numerous and of larger tonnage. Commercial fishing vessels, cruise ships, transport boats, and recreational boats all contribute sound into the ocean. The military uses sound to test the construction of new vessels as well as for naval operations. In areas such as the Gulf of Mexico where oil and gas production takes place, noise originates from the drilling and production platforms, tankers, vessel and aircraft support, seismic surveys,

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and the explosive removal of platforms. The Lamont-Doherty Earth Observatory is planning to conduct calibration measurements of their seismic array in the Gulf of Mexico in the next year and has requested an Incidental Harassment Authority from NOAA Fisheries to incidentally take small numbers of marine mammals.

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The proposed research involves using sound sources and levels that are already very common in the marine environment. For example, Dr. Tyack proposes to conduct 20 airgun playback experiments per year in the Gulf of Mexico. If the source vessel starts 10 km away from the tagged whales, and passes to 5 km beyond the animal, each playback will involve 15 km of transmission and the 20 playbacks will involve no more than 300 miles of transmissions per year. By contrast, the oil and gas industry ran 213,318 miles of transmissions from airgun arrays in the Gulf of Mexico in 2002 (data courtesy of Minerals Management Service). Similarly, there are thousands of sound sources comparable to the whale-finding sonar to be tested in Project 2. The proposed whale-finder sonar will produce one ping lasting up to 400 msec every 15 sec for up to 20 experiments, each lasting between 1-3 hours. Sonars used for depth sounding and bottom profiling often operate in the 1-12 kHz frequency band with source levels similar to that of the whale-finding sonar (Richardson et al.1995). Most ships operate depth sounding sonars continuously while at sea and bottom profilers are a commonly used research tool. The annual operation of the whale-finding sonar in the propose research will involve a maximum of 60 hours. Comparable depth sounding and bottom profiling sonars are operated for millions of hours/year in this same location. Adverse impacts have not been observed from these sources, but there have been few studies looking in detail at exactly how marine mammals respond to them during their dives.

The marine mammals, sea turtles, and their prey that occur in the proposed study areas are regularly exposed to these types of natural and anthropogenic sounds. The cumulative effects of these activities cannot be predicted with certainty. Impacts may be chronic as well as sporadic effects like behavioral changes that can stress the animal and ultimately lead to increased vulnerability to parasites and disease (MMS 2000). The net effect of disturbance is dependent

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on the size and percentage of the population affected, the ecological importance of the disturbed area to the animals, the parameters that influence an animal's sensitivity to disturbance or the accommodation time in response to prolonged disturbance (Gerarci and St. Aubin 1980).

Considering the brief period the proposed research will occur in any location during a single year, the short acoustic transmissions that will be broadcast, the conservative maximum received levels set by Dr. Tyack, the mitigation measures that will be employed, and that these sound sources are not novel to the marine environment, the proposed research will contribute a negligible increment over and above the effects of the baseline activities currently occurring in the marine environment where the proposed research would occur.

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